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THE LOCOMOTIVE EXHIBITS AT THE ST. LOUIS EXHIBITION.

The exhibit of locomotives at the Louisiana Purchase Exhibition at St. Louis is smaller than the exhibit at the Columbian Exhibition at Chicago in 1893, but it comprises a larger number of engines of special interest or special design. The exhibit at St. Louis comprises 42 engines, of which six are of foreign construction and 10 are compounds.

The exhibit at Chicago comprised 62 engines, of which ten were of foreign construction and 20 were compounds. The notable American engines included a four-cylinder tandem-compound freight engine, and passenger engines of the 2-4-2 and 4-6-2 type. The number of compound locomotives, 20 in all, was particularly notable. Among the ten foreign engines were a German two-cylinder, an English three-cylinder and a French four-cylinder compound. There was also an English four-cylinder simple engine (exhibited by its inventor), and although this was peculiar in many respects and did not prove a success when given practical trials, yet two or three English railways have recently introduced four-cylinder simple engines for fast and heavy passenger service. Several of the American locomotives at Chicago were small engines for construction work, logging, etc.; but with the exception of a 15-ton four-wheel saddle-tank engine, all the locomotives at St. Louis are for regular railway service. The American engines at St. Louis also include a greater number of locomotives of unusual types than those at Chicago. Among the six foreign engines at St. Louis are a German three-cylinder compound, and French and German four-cylinder balanced compounds. The locomotives at the two exhibitions may be compared as follows:

	—St. Louis 1904.—		—Chicago 1893.—	
	Total.	Compound.	Total.	Compound.
American	36	7	52	17
Canadian	1	..	1	..
English	..	..	3	1
French	1	1	4	1
German	4	2	2	1
Total	42	10	62	20

Chicago Exhibition, 1893.—American Locomotives: Baldwin, 17 (9 compound); Brooks, 9 (2); Cooke, 2; Lima, 1; Pittsburg, 5 (2); Porter, 5; Rhode Island, 3 (3); Richmond, 1; Rogers, 3; Schenectady, 4 (1); N. Y. Central Ry., 1; Old Colony Ry., 1.

Foreign Locomotives.—Canadian: Canadian Pacific Ry., 1.—English: Great Western Ry., 1; London & Northwestern Ry., 1 (compound); H. Winby, 1. French: Northern Ry., 1 (compound); Western Ry., 1; Paris & Orleans Ry., 1; State Rys., 1 (compound). German: Prussian State Rys., 2 (1 compound).

The locomotives at St. Louis range in size from a small four-wheel tank engine for construction work to the twelve-wheel Mallet steam-truck engine of the Baltimore & Ohio Ry., which is by far the largest engine in the world. Several of the more notable engines have already been described in our columns, and others will be described later. Table I. is a list of locomotive builders, with the number of engines exhibited by each at St. Louis.

TABLE I.—Locomotives at the St. Louis Exhibition.

	Total Engines.	Compounds.
Baldwin Locomotive Works, Philadelphia.	15	5
American Locomotive Co., New York, N. Y.	13	2
Rogers Locomotive Works, Paterson, N. J.	5	0
Lima Loco. & Machine Co., Lima, O.	1	0
F. M. Hicks & Co., Chicago (rebuilt)	1	0
Carney Bros., New York, N. Y.	1	0
Canadian Locomotive Co., Kingston, Ont.	1	0
Société Alsacienne Belfort, France.	1	1
Hanover Mach. Works, Hanover, Germany.	1	1
Henschel & Sohn, Cassel, Germany.	3	1
Total	42	10

Table II. gives the leading dimensions of the several engines, and it will be of interest to give some particulars of the different classes of engines listed in this table.

CLASS A. DUPLEX COMPOUND LOCOMOTIVE.—This engine of the Baltimore & Ohio Ry., which is by far the largest and heaviest ever built, is on the Mallet system, and was described and illustrated in our issue of June 30. It has two groups of driving wheels, with six wheels to each group. The three axles of the rear group are carried in main frames supporting the firebox, and are driven by the high-pressure cylinders; the three axles of the forward group are carried in a swiveling truck under the smokebox, and are driven by the low-pressure cylinders.

CLASS B. THREE-CYLINDER COMPOUND LOCOMOTIVE.—This German engine is designed for speeds of 80 to 90 miles an hour in regular service, and both the engine and tender are enclosed in a steel cab or housing to reduce air resistance. The front driving axle is a crank axle, driven by the high-pressure inside cylinder; the rear driving axle is driven by the low-pressure outside cylinders, and the two pairs of wheels are connected by coupling rods. (Eng. News, Sept. 15, 1904.)

CLASS C. DECAPOD LOCOMOTIVE.—The Atchison, Topeka & Santa Fe Ry. has been introducing a number of interesting types of engines for heavy service on the mountain divisions of its line, and the engine exhibited represents the heaviest of these engines. It has ten driving wheels, with leading and trailing pony trucks; and it is notable, also, as being a tandem compound. This is shown in Fig. 1.

CLASS D. ATLANTIC TYPE.—Of the 11 en-

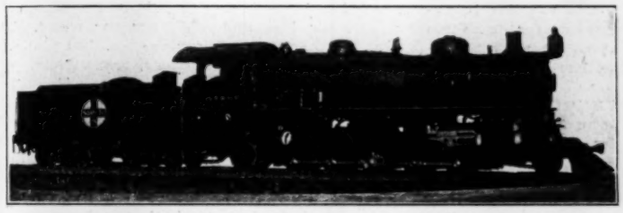

FIG. 1. TANDEM COMPOUND DECAPOD LOCOMOTIVE; ATCHISON, TOPEKA & SANTA FE RY.
Baldwin Locomotive Works, Philadelphia, Pa., Builders.

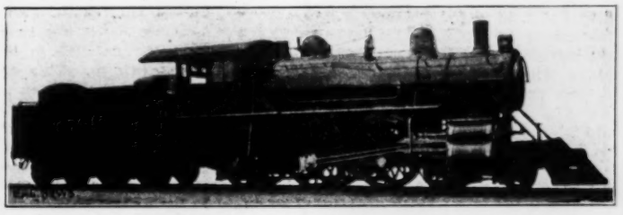

FIG. 2. COMPOUND ATLANTIC ENGINE; CHICAGO, BURLINGTON & QUINCY RY.
Baldwin Locomotive Works, Philadelphia, Pa., Builders.

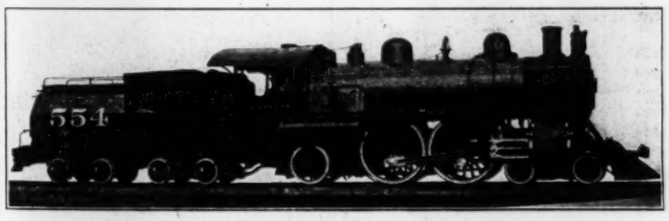

FIG. 3. ATLANTIC ENGINE WITH VANDERBILT TENDER; CHICAGO & ALTON RY.
Baldwin Locomotive Works, Philadelphia, Pa., Builders.

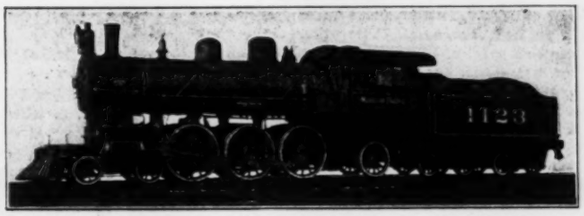

FIG. 4. PACIFIC TYPE PASSENGER ENGINE; MISSOURI PACIFIC RY.
American Locomotive Co., New York, N. Y., Builders.

gines of this class, five are four-cylinder compounds, and four of these are balanced compounds: No. 4 is on the Coles system (Eng. News, June 23, 1904), No. 5 on the Vauclain system (Eng. News, March 31, 1904), No. 6 (French) on the De Glehn system (Eng. News, March 31 and May 26, 1904), and No. 7 (German) on the Von Borries system. The special features of these several systems were described in an editorial on balanced-compound locomotives in our issue

service on nearly every railway, and is well represented by nine engines of ordinary design and construction. Two engines of this class (No. 23 and No. 31) are shown in Figs. 7 and 8. The engine of the Delaware, Lackawanna & Western Ry. (No. 32) has a Wootten firebox. In view of the extent to which compounding has been adopted for freight engines, it is rather remarkable that there should be only one compound among these. A Michigan Central Ry. two-cyl-

In considering the dimensions given in the [illegible] it will be seen that the largest driving wheel [illegible] those of the German high-speed engine (No. [illegible] 7 ft. 2⅝ ins., while the engine for the Chi[illegible] Burlington & Quincy Ry. (No. 8) has wheels [illegible] 0¼ in.; and the French engine for the Pen[illegible] vania R. R. (No. 6), 6 ft. 8 ins. Of six-cou[illegible] engines, the Lake Shore & Michigan Sout[illegible] Ry. (No. 23) has wheels 6 ft. 8 ins. diameter, [illegible] the Union Pacific Ry. engine (No. 18) has wh[illegible]

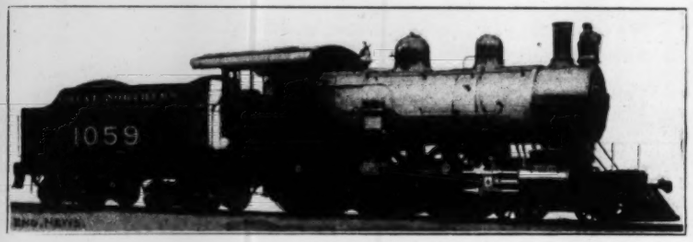

FIG. 5. TEN-WHEEL ENGINE; GREAT NORTHERN RY.
Rogers Locomotive Works, Paterson, N. J., Builders.

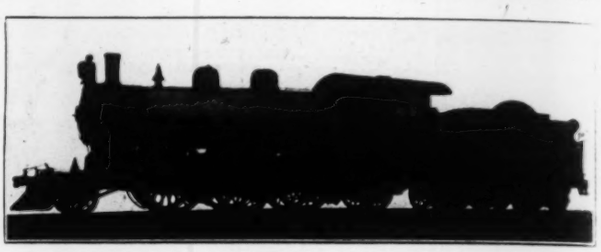

FIG. 6. PRAIRIE TYPE PASSENGER ENGINE; LAKE SHORE & MICHIGAN SOUTHERN RY.
American Locomotive Co., New York, N. Y., Builders.

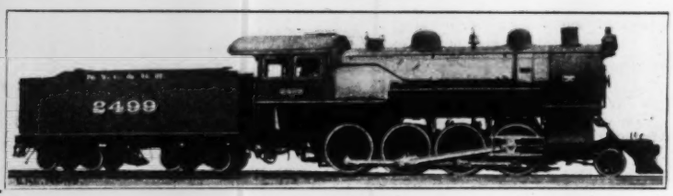

FIG. 7. CONSOLIDATION FREIGHT ENGINE; NEW YORK CENTRAL & HUDSON RIVER RY.
American Locomotive Co., New York, N. Y., Builders.

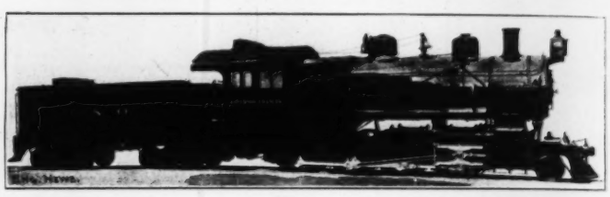

FIG. 8. CONSOLIDATION FREIGHT ENGINE; BALTIMORE & OHIO RY.
Rogers Locomotive Works, Paterson, N. J., Builders.

of March 31, 1904. The French, one German, and the two American balanced compounds we have already described, and the other German engine we shall describe later. Engine No. 8, shown in Fig 2, is of the ordinary Vauclain system, having two superimposed cylinders on each side, with their piston rods attached to a single crosshead. The other six engines of the Atlantic type are all simple, and one of these (No. 12) is shown in Fig. 3. This is for the Chicago & Alton Ry., and has a Vanderbilt tender.

CLASS E. EIGHT-WHEEL TYPE.—This type is one of the most extensively used in ordinary railway service, although for high-speed passenger trains it is being largely superseded by engines of the Atlantic type. The only large engine of the eight-wheel type is the "Director-General," which formed a prominent feature of the Baltimore & Ohio Ry. exhibit at the Columbian Exhibition of 1893. This is No. 15 in the table, and is a Vauclain compound. The other eight-wheel engines are a rebuilt engine and a Canadian engine of 3 ft. 6 ins. gage.

CLASS F. PACIFIC TYPE.—This type of locomotive is to the ten-wheel type what the Atlantic is to the eight-wheel type. First among the three engines exhibited is the immense engine of the Union Pacific Ry., designed for fast work with very heavy trains on steep grades. Fig. 4 shows the engine of the Missouri Pacific Ry., which is attached to this railway's train in the exhibition.

CLASS G. TEN-WHEEL TYPE.—The two locomotives of this type do not present any special features, but the one shown in Fig. 5 is a good example of this class of engine.

CLASS H. PRAIRIE TYPE.—This type is similar to the mogul type, with the addition of a pair of trailing wheels. It was introduced for freight service on the Chicago, Burlington & Quincy Ry. (Eng. News, May 30, 1901). The engine exhibited, however, is for fast passenger service on the Lake Shore & Michigan Southern Ry., although few railways now care to use engines with two-wheel leading trucks in this class of service. This is shown in Fig. 6.

CLASS I. MOGUL TYPE.—The four engines of this type are representative of ordinary practice, but include a very neat looking engine of narrow gage (3 ft. 6 ins.) for the Kiushiu Ry., Japan.

CLASS J. CONSOLIDATION TYPE.—This type of engine is commonly used for heavy freight

inder compound consolidation was sent to the testing plant, but did not remain on exhibition.

CLASS K. SWITCHING LOCOMOTIVE.—This is a large six-wheel engine for the Manufacturers' Ry., of St. Louis. It is peculiar in appearance, as it has been prepared for exhibition by being finished in bright colors with nickel-plated fittings. This engine has a swallow-tail tender.

CLASS L. LIGHT TANK ENGINES.—Of these three locomotives, the first is an American saddle-tank engine (3 ft. gage) for construction work. The two German engines have side tanks, and are of a class for light railway or plantation work. In both cases outside cylinders and the Allan link motion (with straight link) are used, but the link is driven from a double return crank instead of from an eccentric. The four-wheel engine is of 4 ft. 8½ ins. gage, while the six-wheeled engine is of 3 ft. gage.

CLASS M. GEARED ENGINE.—This engine is of the well-known Shay type, in which vertical cylinders at one side of the engine drive a crank shaft which is connected by flexible couplings to shafts on the truck frames. These shafts carry bevel pinions meshing with bevel gears bolted to the faces of the driving wheels. The engine is carried on two four-wheel trucks, and the tender is carried on a similar truck, whose wheels are also driven in the same way. The weight of the tender varies from 11½ tons empty to 24 tons with full load.

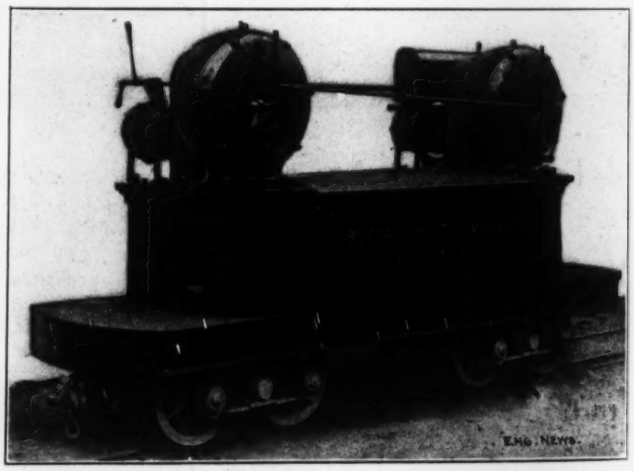

FIG. 9. STORAGE BATTERY LOCOMOTIVE FOR INDUSTRIAL PLANTS.
C. W. Hunt Co., West New Brighton, N. Y., Builders.

CLASS N. MINIATURE ENGINES.—This represents the little eight-wheel (4-4-0) engines which operate the miniature railways of 15 ins. gage in the exhibition grounds. These were built by Cagney Bros., of New York, who also have an engine with the other locomotive exhibits.

6 ft. 5 ins. diameter. The heaviest engine is the Mallet compound (No. 1), 167 tons. Exclusive of this the heaviest engines are the decapod (No. 3) and consolidation (No. 28) freight engines, weighing 144 and 109 tons, with 117 and 98 tons on the drivers, or 11¾ and 12¼ tons per wheel. The heaviest passenger engines are No. 18 and No. 4, which weigh 111 and 100 tons, respectively, with 71 and 55 tons on the drivers, giving 11 5-6 and 13¾ tons per wheel.

The largest diameter of cylinders is found in the 32-in. and 35-in. low-pressure cylinders of the Baltimore & Ohio R. R. duplex engine (No. 1) and the two-cylinder compound of the Norfolk & Western Ry. (No. 35). The stroke in both these engines and also in several other engines is 32 ins. The largest cylinders of simple engines are those of the New York Central Ry. engine, No. 28, being 23 × 32 ins. The largest boilers are those of engines Nos. 1 and 28, being 84 and 81⅝ ins. respectively. In boiler pressure, 200 lbs. is general, with 235 lbs. as the maximum. The French engine, No. 6, is designed for 227 lbs., while the decapod engine No. 3 carries 225 lbs., and two of

the Atlantic type balanced compounds carry 220 lbs. Wide and large fireboxes are the rule, but there is only one engine (No. 32) having the Wootten firebox for burning small anthracite coal. The largest number of tubes is 438 in the 81⅝-in. boiler of the New York Central engine, No. 28; these are only 15 ft. 6 ins. long. The Baltimore & Ohio engine, No. 1, has 436 tubes in its 84-in. boiler, but these are 21 ft. long, which is the greatest length of any engine in the list, although two engines, Nos. 3 and 18, have 20-ft. tubes. The greatest heating surface is also possessed by the immense duplex engine, No. 1, with 5,586 sq. ft. and 732 sq. ft. of grate area. The next in rank are the 4,796 and 3,901 sq. ft. of the decapod and consolidation engines, Nos. 3 and 28 (with 58.5 and 57.9 ft. of grate); but the Wootten firebox of engine No. 32 has 95 ft. of grate area to 2,773 ft. of heating surface. Several engines have tenders carrying 10 tons of coal, while the maximum is 15 tons. The tender tank capacity is generally 6,000 to 7,000 gallons, with a maximum of 8,500 gallons.

Besides the locomotives themselves, there are interesting exhibits of slide and piston valves, sand-jet apparatus, etc., while there are two exhibits of cylinders and valves cut in half longitudinally so as to show the parts in their relative positions. The exhibit of the American Locomotive Co. also includes two special devices: (1) the Nunnally device for setting crank pins and for determining whether cranks are properly set, this is in use at the company's Richmond shops; (2) the Livtschak speed and location indicator and recorder; this is a German invention and is used on the Russian government railways. On a revolving dial is printed the profile of the road, with stations, grade crossings, etc., marked. A somewhat similar device has been used in this country, and was described in our issue of Oct. 27, 1898.

A 70-ft. steel turntable is exhibited by the Chicago Bridge & Iron Works, and is mounted on a concrete pedestal or pier, its rails being about 10 ft. above the floor. It is of the center-bearing type, with no end supports, and upon it stands an Atlantic engine of the Cleveland, Cincinnati, Chicago & St. Louis Ry. (No. 10). The turntable revolves slowly, being driven by an electric motor. The driving wheels of the engine also revolve, being raised clear of the rails and driven by horizontal electrically-operated friction wheels, which bear against the inside of the rim of the engine wheels. The turntable has two deck plate girders, 70 ft. long, 16½ ins. deep at the ends and 4 ft. 10½ ins. deep at the middle; these are 5 ft. 6 ins. apart, c. to c., and are connected by top and bottom lateral bracing.

ELECTRIC LOCOMOTIVES.

There are about eight electric locomotives exhibited, all of the type used for light work in shops, mines, etc. These may be classed as follows:

STORAGE BATTERY SYSTEM.—The Westinghouse Electric & Mfg. Co., of Pittsburg, has a steel frame flat car operated by batteries and motors placed beneath the floor; this is intended for handling material in shops and power stations. The C. W. Hunt Co., of New York, has a narrow gage (21½ ins.) locomotive mounted on a pair of trucks having outside-flanged wheels of the Hunt system; the box containing the batteries is mounted on a steel underframe, and at each end of the box is a motor and gearing, from which the truck axles are driven by silent chain transmission. The top and bottom bars of the truck frames are flat plate springs connecting the boxes, which have roller bearings for the journals. Locomotives of this class are extensively used for handling cars in industrial works, and one of these is shown in Fig. 9.

TROLLEY-WIRE SYSTEM.—The General Electric Co., Schenectady, N. Y., and the Baldwin Locomotive Works, Philadelphia, Pa., have four-wheel electric locomotives of the familiar type employed in mining work. Each of the Baldwin engines has a 50-HP. single-reduction Westinghouse motor geared to each axle; they weigh 21,500 and 26,700 lbs., and their drawbar pull is 4,300 to 6,000 lbs. There is also a Baldwin engine of the type used at industrial works, having a high cab, and with a pair of jointed diamond frames carrying

TABLE No. II.—DIMENSIONS OF LOCOMOTIVES AT THE ST. LOUIS EXHIBITION.

No.	Railway.	Builder.	Traffic.	Driv. wheels ins.	Wheelbase. Driving ft. ins.	Wheelbase. Engine ft. ins.	Weight. On drivers. tons.	Weight. Total. tons.	Simple Comp.	Cylinders. No.	Cylinders. Diam. ins.	Cylinders. Stroke ins.	Boiler diam. ins.	Steam press. lbs.	Firebox ins.	Tubes. No.	Tubes. Diam. ins.	Tubes. Length. ft.	Tubes. Length. ins.	Heating Surface. Tubes. sq. ft.	Heating Surface. Total. sq. ft.	Grate area. sq. ft.	Coal tons.	Water gals.
									CLASS A: MALLET DUPLEX; 0-6-6-0.															
1	B. & O.	Am. Loco. Co.	Frt.	56	10	2	30	8	167	167	Dup.-co.	4	20, 32	32	84	235	108 x 96	436	2¼	21	0	5,366	5,586	72.3	13	7,000
									CLASS B: SPECIAL HIGH SPEED; 4-4-4.															
2	Prussian State	Henschel	Pass.	86⅝	8	4¾	37	8	32	85	Comp.	3	20½	24⅞	63¾	200	96 x 72	345	1¾	16	4½	.....	2,776	45.4	7	4,400
									CLASS C: DOUBLE-END DECAPOD; 2-10-2.															
3	A. T. & S. F.	Baldwin	Frt.	57	19	9	35	11	117	144	Tan.-co.	4	19	32	78¾	225	108 x 72	391	2¼	20	0	4,586	4,796	58.5	10	8,500
									CLASS D: ATLANTIC; 4-4-2.															
4	N. Y. Con.	Am. Loco. Co.	Pass.	79	7	0	27	9	55	100	Bal.-co.	4	15½, 26		72¼	220	96 x 76	399	2	16	0	3,248	3,448	50.2	10	6,000
5	A. T. & S. F.	Baldwin	"	79	6	10	30	3	50	86	"	4	15, 25		66	220	108 x 66	273	2	18	10	3,016	3,206	49.5	12	8,500
6	Pennsylvania	Soc. Alsacienne	"	80¾	7	0½	28	6½	42	80	"	4	14½, 23½		59½	227	124 x 48	139	2¼	14	5¼	2,436	2,617	34.0	11	5,500
7	Prussian State	Han. Mach. Wks.	"	78	6	11⅜	29	6¼	33½	66	"	4	14½, 22½		57	200	75 x 66	241	2	14	7½	1,632	1,740	28.0	6¼	4,200
8	C. B. & Q.	Baldwin	"	84¾	7	8	27	8	43	91	Vau. Co.	3	15, 25		64	210	96 x 66	330	2	15	6	2,886	3,092	44.1	10	6,000
9	Ill. Con.	Rogers Loco. Wks.	"	79	7	3	27	8	51	99	S.	2	20		68	200	102 x 72	391	2	16	10	2,954	3,134	51.0	15	7,000
10	C. C. C. & St. L.	Am. Loco. Co.	"	79	7	6	29	10	50	93	"	2	20		68½	200	97 x 68	362	2	16	0	3,015	3,196	44.8	12	7,500
11	Vandalia	Am. Loco. Co.	"	79	7	0	27	3	54	92	"	2	21		72¾	200	96 x 76	351	2	16	0	2,923	3,100	50.2	14	7,500
12	C. & Alton	Baldwin	"	81	7	0	27	7	52	92	"	2	20		70	200	108 x 66	247	2	16	0	2,475	2,655	49.5	10	7,000
13	B. & O.	Am. Loco. Co.	"	80	7	6	30	9½	55	90	"	2	22		67	205	111 x 72	313	2	15	7	2,573	2,717	45.5	10	6,000
14	Nor. & West.	Baldwin	"	79	6	10	26	8	40	85	"	2	19		62	200	106 x 64	326	2	16	0	2,717	2,879	46.1	10	6,000
									CLASS E: EIGHT-WHEEL; 4-4-0.															
15	B. & O. (1893)	Baldwin	Pass.	78	7	6	22	4	39	61	Vau. Co.	4	13½, 23		24	180	107½ x 84	251	2	11	10	1,544	1,693	24.7	4½	3,500
16	Pr. Ed'a Id.	Canad. Loco Wks.	"	54	7	9	19	8	23	35	S.	2	15		20	....	66½ x 33	170	1¾	9	6	746	836	.....	2½	2,200
17	(Rebuilt)	F. M. Hicks	"	68	8	10	23	10	37⅜	53⅜	S.	2	18		26	160	72 x 84	201	2	12	6	1,307	1,448	16.7	8	4,000
									CLASS F: PACIFIC; 4-6-2.															
18	Union Pac.	Baldwin	Pass.	77	13	4	33	4	71	111	S.	2	22		28	70	200	108 x 66	245	2¼	20	0	2,874	3,053	49.5	14	7,000
19	St. L. & S. F.	Baldwin	"	69	12	0	30	0	57	95	S.	2	22		26	64	200	108 x 78	249	2¼	18	7	2,713	2,863	43.3	10	6,000
20	Mo. Pac.	Am. Loco. Co.	"	69	12	4	31	8	61	91	S.	2	20		26	64	200	78 x 64	256	2¼	18	6½	2,778	2,930	42.9	10	5,000
									CLASS G: TEN-WHEEL; 4-6-0.															
21	Norf. & West.	Baldwin	Pass.	68	13	1⅜	24	4½	65	83	S.	2	20		28	66	200	42 x 112½	281	2¼	14	5½	2,370	2,559	32.6	10	6,000
22	Gt. Nor.	Rogers Loco. Wks.	"	73	13	6	24	11	67	81	S.	2	19		28	66	210	112 x 42	280	2	14	3	2,089	2,292	32.0	11	6,000
									CLASS H: PRAIRIE; 2-6-2.															
23	L. S. & M. S.	Am. Loco. Wks.	Pass.	80	14	0	31	10	71	95	S.	2	20½		28	66	200	85 x 84	344	2	19	0½	3,413	3,597	48.5	13	6,000
									CLASS I: MOGUL; 2-6-0.															
24	Norf. & West.	Baldwin	Frt.	68	13	1½	24	4½	65	83	"	2	20		28	66	200	112½ x 42	281	2¼	14	5½	2,370	2,559	32.6	10	6,000
25	Mo., K. & T.	Baldwin	"	63	15	0	23	7	66½	77½	"	2	21		25	64	200	110 x 30	310	2	12	8	2,082	2,234	46.7	10	6,000
26	St. L. So. W.	Rogers Loco. Wks.	Frt.	61	14	8	22	9	63	73	"	2	20		24½	64	200	104 x 30	270	2	12	3½	1,735	1,897	28.9	12	5,500
27	Kiushiu (Japan)	Am. Loco. Wks.	Pass.	54	11	11	19	5	39	46	S.	2	17		26	58	180	82 x 20¾	180	2	11	1	1,091	1,197	16.9	2½	2,500
									CLASS J: CONSOLIDATION; 2-8-0.															
28	N. Y. Central	Am. Loco. Wks.	Frt.	63	17	0	25	11	98	109	S.	2	22		32	81½	200	105 x 75¼	438	2	15	6	3,693	3,993	54.0	12	7,000
29	So. Pacific	Baldwin	"	57	15	8	24	4	97	104	"	2	22		30	80	200	108 x 66	413	2	15	0	3,226	3,397	49.5	14	7,000
30	Erie	Am. Loco. Wks.	"	62	17	0	26	11	80	101	"	2	22		32	74½	200	104½ x 75¾	372	2	15	10	3,166	3,231	54.4	12	7,000
31	Balt. & Ohio	Rogers Loco. Wks.	"	56	16	6½	24	9	86½	97	"	2	22		28	76	205	107½ x 66	359	2¼	14	9½	2,544	2,775	55.3	12	7,000
32	D. L. & W.	Baldwin	"	57	16	10	24	8	86	96	"	2	21		26	70¾	200	120¼ x 76¾	333	2	14	7	2,546	2,746	54.0	15	7,000
33	Ill. Cent.	Rogers Loco. Wks.	"	65½	16	0	24	8	82	95	"	2	20		28	70	200	90 x 72	370	2	14	9	2,887	3,024	46.8	10	6,000
34	Ches. & Ohio	Am. Loco. Wks.	"	56	17	0	25	8	83	93	"	2	22	23, 32	32	68	200	121 x 41¾	306	2¼	14	6	2,593	2,788	35.0	10	6,000
35	Norf. & West.	Baldwin	"	56	15	6	24	11	76	87	"	2	21	Comp.	30	64	200	101 x 64¾	252	2¼	14	6	2,140	2,390	45.0	10	6,000
36	Norf. & West.	Baldwin	"	56	16	6	24	11	76	87	"	2	21	"	30	64	200	101 x 64¾	252	2¼	14	6	2,140	2,390	45.0	10	6,000
									CLASS K: SWITCHING; 0-6-0.															
37	Manfra	Am. Loco. Wks.	"	50	11	3	11	3	72	72	S.	2	20		26	64	180	66 x 63	279	2	15	0¾	2,185	2,308	28.1	7½	6,000
									CLASS L: LIGHT TANK ENGINE.															
38	Saddle tank	Am. Loco. Wks.	4-whl.	33	5	0	5	0	15½	15½	S.	2	10		16	34	150	34 x 41¾	94	1½	8	2¾	303	342	7.0	¾	400
39	Side tank	Henschel	6-whl.	23¾	4	7½	4	7½	23	7¾	"	2	13¾		11½	...	170	.....	....	....	....	....	....	157	4.1	¾	180
40	Side tank	Henschel	4-whl.	37½	8	2½	8	2½	23	23	"	2	13¾		19½	...	170	.....	....	....	....	....	....	622	11.0	¾	726
									CLASS M: GEARED ENGINE.															
41	.....	Lima Loco. Wks.	12-whl.	36	4	4	39	11¼	65	65	S.	3	12		15	44¼	200	72½ x 44	156	2	10	11¼	868	975	21.1	5	3,000
									CLASS N: MINIATURE.															
42	World's Fair Ry.	Cagney Bros.	Pass.	10½	1	4	4	0	½	½	S.	2	2¾		4	14	150	18 x 11	22	1¼	2	0	.....	.....	.....	.....	25

the contact wheels (for a double trolley system) instead of the usual trolley pole; this has two 35-HP. motors, and the engine weighs 20,000 lbs.

THIRD-RAIL SYSTEM.—The Morgan Electric Machine Co., East Chicago, Ind., has a narrow-gage railway running through the outdoor mining exhibits, and operated by a locomotive taking current from a center rack rail by means of a cog wheel. This system is used in a number of coal mines, and was described and illustrated in our issue of March 17.

ELECTRIC CARS.—There is a very large exhibit of electric cars for city and interurban railways; and there are also a number of trucks for such cars. The only specially notable car, however, is one designed especially for high speeds, having six-wheel trucks and two motors of 200 HP. on each truck. This car was described and illustrated in our issue of Aug. 25.

THE NEW WATER SUPPLY OF TROY, N. Y.

By William G. Raymond.*

The city of Troy, N. Y., formerly included a strip of land varying from a quarter of a mile to a half mile in width and extending up and down the east shore of the Hudson River for about four miles at the head of navigation. The tide is felt at Troy below the State dam and the general level of the surface of the ground on which the old town was built is about 30 ft. above tide.

In recent years the corporation limits were considerably extended to the eastward, taking in an area of high ground which rises abruptly from the narrow strip along the river, to a general level of 300 ft., with points in the extreme eastern side about 480 ft. above tide. Yet more recently the corporation boundaries have been extended south, east and north, including on the north what was formerly the village of Lansingburgh, which had a gravity water supply system of its own, additions to which were under construction when the village came into Troy. The additions consisted of a dam and pipe line to divert and deliver water from the Deepkill area shown on the accompanying map.

After the not uncommon beginning of many years ago of a company supplying water from a hillside spring through wooden pipes, the city of Troy acquired rights in a small stream known as the Piscawankill, which rises to the northeast of the city and flows through the city from east to west to the Hudson River.

The first reservoir on this stream was well down the stream and was early found to be of insufficient capacity and altitude for the growing demand. Additional storage was obtained by enlarging a spring-water pond on the drainage area to a reservoir for impounding the water of the stream. This reservoir was called Brunswick Lake. Later a second reservoir was built adjoining this lake, and called Vander Heyden Lake.

At first only the low land was supplied with water, but increased transportation facilities caused the city to spread up the hill to the east, and two new services were installed, so that for many years the city has been supplied by three services—low, middle and high—each receiving water from the Piscawankill from reservoirs built at various altitudes. The Piscawankill has a drainage area of about three square miles, and was outgrown many years ago.

Several streams of considerable size, although flashy, find their sources in the mountains east of the city, and when it became necessary some thirty or more years ago to increase the supply of water, sharp controversies arose as to whether these streams should be used or Hudson River water pumped to the city. The river triumphed, and for the last 30 years the low service has been supplied with Hudson River water pumped from a point near the northern end of the former village of Lansingburgh, through 16,000 ft. of 30-in. cast-iron force main, to one of the reservoirs built on the Piscawankill, at an elevation of 231 ft. above tide. This reservoir is a storage reservoir, from which the water is dropped about 40 ft. to a distributing reservoir holding only a few hours supply.

The pumping plant consists of two Holly pumping engines of 6,000,000 gallons daily capacity each, with the necessary boilers, etc. This plant was installed under the direction of Prof. D. M. Greene, then Engineer to the Board of Water Commissioners.

The several drainage areas, reservoirs and conduit lines now a part of the Troy water supply system are shown on the accompanying map, Fig. 1. The Piscawankill was relied on to supply the middle and high services, and has until within a few years been adequate for this purpose, supplying as well considerable quantities of water to the low service in times of high flow.

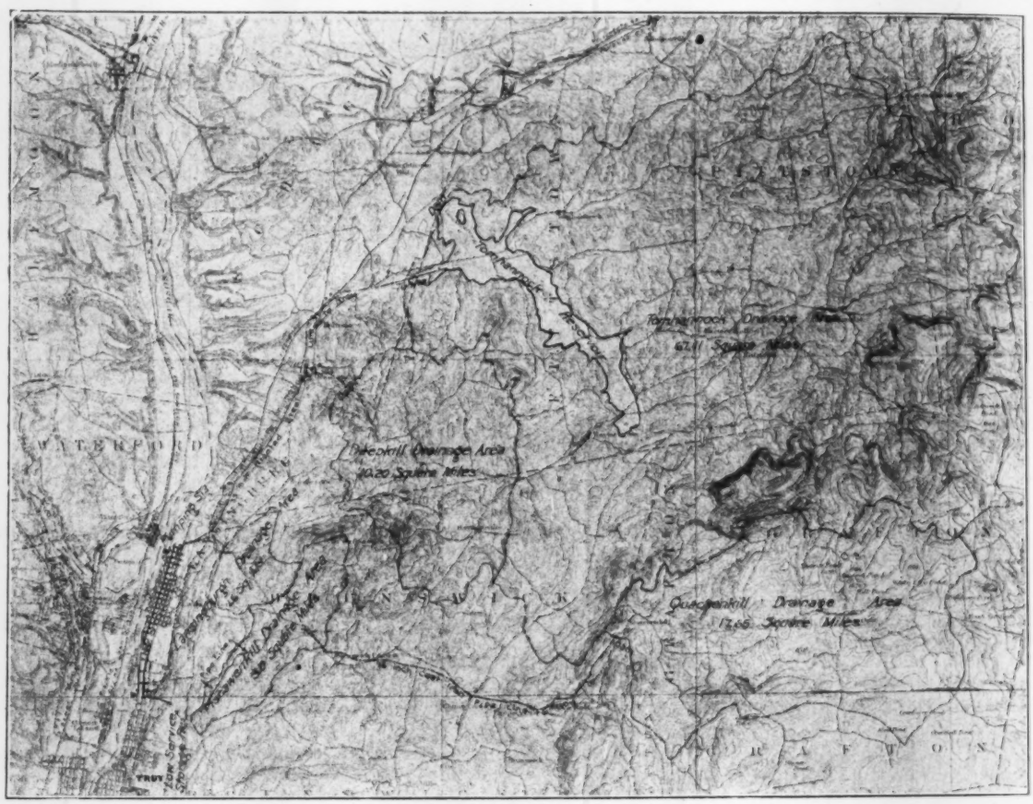

FIG. 1. MAP SHOWING DRAINAGE AREAS IN THE VICINITY OF TROY, N. Y.

About eleven years ago the demand of the low service about equaled the capacity of one pump, and as the city was at this time extending its sewerage system and compelling connections with it, the necessity of providing additional water supply at an early day became apparent. Attention was again directed to the mountain streams on the east of the city, and the late Elnathan Sweet and William G. Raymond were asked to report on the best method for obtaining an additional supply of water. These gentlemen considered increasing the Hudson River pumping plant, and also gravity supplies from the Poestenkill, Quackenkill and Wynantskill streams, shown on the map, Fig. 1. The Wynantskill was considered too well developed for power to warrant purchase. Beside many mills and factories along its banks, it was used to drive the famous great wheel of the Burden Iron Co. An increased pumping plant was found to be cheaper in first cost, but more expensive in ultimate cost than a gravity supply from the upper Poestenkill and Quackenkill. Because of this and the fact that examinations by Dr. William P. Mason, of the Rensselaer Polytechnic Institute, showed the water of the mountain streams to be much more suitable for domestic supply than the Hudson River water, a plan was formulated and recommended, contemplating the construction of several storage reservoirs on the mountain drainage areas, with conduits from diverting dams to be built at the lowest practicable points on the drainage areas. These recommendations met with favor, the necessary legislation was secured, Mr. Raymond was appointed chief engineer and directed to prepare the necessary detail plans. These plans were practically completed when political differences in the city put a stop to all further work.

In 1895 a serious shortage occurred in the upper services, but opposing powers were still in control of the water board and the legislative branch of the city government and nothing was done in the way of providing a new supply. In the meantime the U. S. Geological Survey had completed its topographical charts of the district, and Mr. Raymond found on one of these sheets what seemed to be a particularly favorable site for a storage reservoir on a stream known as the Tomhannock, rising in the mountains just north of the sources of the Quackenkill, and flowing northwesterly to the Hoosic River. The site seemed to be at an elevation sufficient to supply the low, and possibly the middle services, and was fed by a drainage area of about 67 sq. miles. It seemed that a single reservoir here would do more than the several reservoirs previously planned for the smaller streams. This was brought to the attention of the board of water commissioners, and in 1897 the board asked Messrs. Sweet and Raymond to again report on the question of additional supply. The consumption of water in the city had so much increased in four years that it was at once seen that it would not do to advise so small a beginning as was advised in 1893. Preliminary examinations of the Tomhannock site made it certain that an

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artificial lake about five miles long could be developed by the construction of a comparatively short earth dam, about 70 ft. high, and that at least 8,000,000,000 gallons storage could be provided, which, with the drainage area of 67 sq. miles, would make the system good for not less than 25,000,000 gallons daily, and probably 30,000,000 gallons. The reservoir as finally planned and now under construction will hold nearly 12,000,000,000 gallons. Messrs. Sweet and Raymond reported the advisability of utilizing the Tomhannock for the low service, and the development of the Quackenkill, to a less degree than formerly proposed, for the high and middle services. Nothing was done in the matter until 1900, when a new administration elected the previous fall on the water supply issue began operations. Authority to spend $1,250,000 for an additional water supply was obtained from the legislature, and the work of planning for construction was begun under the direction of Mr. John Phelan, Commissioner of Public Works, and William G. Raymond, Consulting Engineer.

THE QUACKENKILL DIVISION.

The plan for the development of the Quackenkill for a high service supply included the construction of a small concrete and earth diverting dam, with necessary gatehouse and valve chambers, as shown in Fig. 2, and 32,717 ft. of conduit line. Immediate development of storage reservoirs other than those already existing on the drainage area was deemed unnecessary to provide the smaller quantity of water required from this stream under the new plan. The conduit line was designed to carry 5,000,000 gallons daily, was laid to an irregular line and undulating profile, and was compounded of 29,550 ft. of 16-in. cast iron pipe from the dam to the top of the last hill, and 3,167 ft. of 12-in. pipe for the remainder of the distance. The conduit conveys water from the upper 17½ sq. miles of the Quackenkill drainage area to Brunswick Lake, the highest of the present Troy reservoirs, from where the water formerly ran through about 9,000 ft. of open creek channel to the high and middle service distributing reservoirs. The conduit terminal is of rather unusual form. The pipe was extended some distance into the lake, turned upward, and terminated in a mass of concrete of the form shown in Fig. 3. The top of the terminal is about 3 ft. below high water in the lake. It is drained by a small pipe at the bottom. There has been no trouble from wash or ice.

The conduit line probably enjoys the distinction of being the most costly line of its size and length recently laid in this country. About half its length is through the valley of the Quackenkill, along a public highway in a narrow gorge, through excavation that was almost one continuous mass of boulders of all sizes and of solid quartzite rock; the other half is through cultivated fields in soil that is a firm clay, mixed with gravel and some rock. The entire work was done by day labor, a large portion of which was of a very unsatisfactory character, under unskilled foremen, few beside the superintendent having had previous experience in this class of work. The day was nominally eight hours, but really not more than 7½ to 7 hours. All tools were purchased new. As many as 500 men were employed at one time. Work was begun on April 29, 1901, and practically completed so that water was turned through on Nov. 2, 1901. Exclusive of hauling, the total cost of labor was $82,931, or about $2.54 per ft. The cost of right-of-way 30 ft. wide varied from 7 to 25 cts. per lin. ft., and averaged about 15 cts. per ft., exclusive of legal charges. Such consolation as may be is found in the thought that about the whole labor cost was kept in the city, only citizens being employed.

The diverting dam and reservoir was contract work, let at the following estimate and prices, the city furnishing the cement:

Clearing and grubbing	3.4	acres at	$26.00
Earth excavation for dam	630	cu. yds.	.30
Rock excavation for dam	610	" "	1.50
Earth embankment for dam	775	" "	.60
Earth excavation for road	1,710	" "	.30
Rock excavation for road	385	" "	1.50
Earth embankment for road	1,140	" "	.01
Concrete in place	1,065	" "	3.51
Dry wall in place	32	" "	3.40
Pavement in place	195	sq. yds.	1.70
Slope wall in place	80	" "	1.00
Wrought-iron	5,600	lbs.	.06
Two gate houses			250.00
Furnishing and setting two 24-in. sluice gates			250.00
Laying and fitting 130 ft. of 16-in. cast-iron pipe			104.00

The rock was a very hard quartzite, exceedingly difficult to excavate and crush. Sand of even passable quality was not to be found in the immediate vicinity. The contractor had no adequate plant, lost money, and under pressure and a small bonus gave up the work when it was perhaps less than half completed. The completion was let at the following prices:

Clearing and grubbing	3.4	acres at	$90.00
Earth excavation for dam	15	cu. yds.	.40
Rock excavation for dam	15	" "	1.95
Earth embankment for dam	390	" "	.60
Earth excavation for road	360	" "	.45
Rock excavation for road	150	" "	1.95
Removal of waste material	630	" "	.50
Concrete	327	" "	4.85
Pavement	275	sq. yds.	1.90
Wrought-iron	5,600	lbs.	384.00
Furnishing and setting two gates			345.00
Two gate houses			400.00

The total payments on account of the dam and reservoir, exclusive of land, engineering and inspection, amounted to $16,073.

Provision was made in the gate and valve chambers for a second conduit line, and the second line was laid between the two chambers, as shown in Fig. 2. The grating, or screen (see detail in Fig. 2) in the gate chamber consists of removable bars resting in slots cut in Z bars. There are no cross bars to interfere with raking.

A Venturi meter tube and registering apparatus were placed on the conduit line, the particular position on the profile being chosen after consultation with the makers. It was located on a descending grade at a point where at times of small flow the pipe does not run full. This was a mistake. Such a meter should be located where there will always be a pipe full of water, and hence on an undulating profile, certainly the proper place is on an up grade or very near the foot of a down grade.

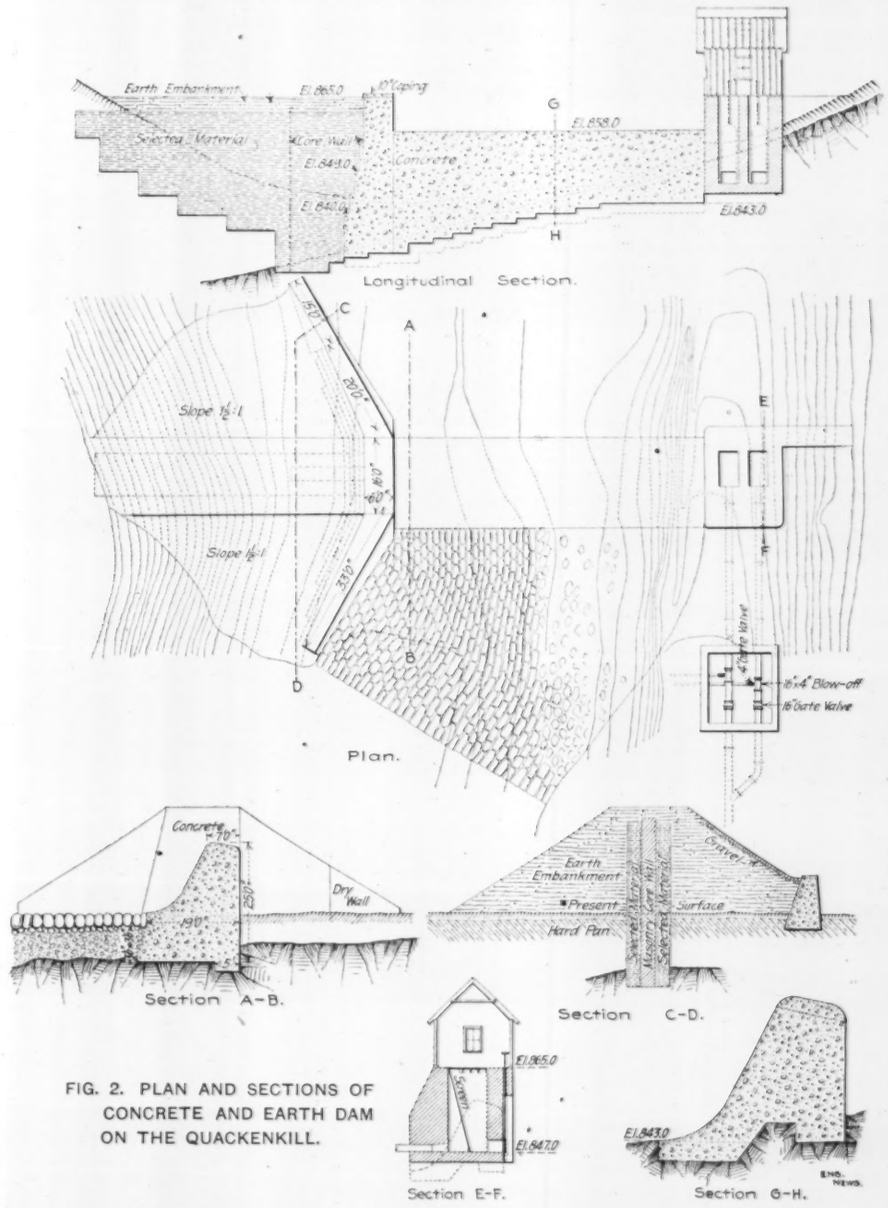

FIG. 2. PLAN AND SECTIONS OF CONCRETE AND EARTH DAM ON THE QUACKENKILL.

The cost of the entire Quackenkill system, exclusive of riparian damages, yet to be determined, was $182,695. Of this, $10,780 was for engineering and inspection (large because of the long time taken to build the dam), $2,661 was for legal expenses and $2,981 was for advertising, printing and incidentals.

It has been mentioned that the water from Brunswick Lake for the high and middle services ran down about 9,000 ft. of open creek to the several distributing reservoirs. The high service distributing reservoir was at an elevation insufficient to supply the higher points of the city. Until the necessary additional water was had it would have been useless to try to remedy this defect. When the new supply became available it was determined to supply the additional ter-

ritory so far as possible. To do this the high-service 20-in. distributing main was extended along a highway and through fields for the 9,000 ft. to the lower compartment of the Brunswick-Vander Heyden reservoir. Experience with day labor having proven unsatisfactory, the city furnished the pipe on board cars in Troy, and let the hauling and laying separately to contractors. The contract for the laying, including the furnishing of lead and jute packing, was let at the following prices:

Pipe laid in rock	1,000 ft. at	$2.20
Pipe laid in earth	8,156 "	1.345
Rock in road grading	275 cu. yds.	1.75
Building culvert		150.00
Building wells and setting valves		150.00

There was apparent competition, with indications that it was not real, and as the price was high, the engineer advised the rejection of the bids, but was overruled by the Board of Contract and Supply. Careful watch was kept of the cost of the work to the contractor, and while it is impossible to estimate all minor details with absolute precision, it is practically certain that the work did not cost in excess of $7,000. The total payment was $14,436, showing a profit of over 100%.

A new gate-house was necessary at Vander Heyden Lake, to connect the lake with the new conduit. Advertisements for the construction of this gate-house resulted in a single bid from the parties who laid the pipe. The bid was about 47% in excess of the engineer's estimate, and by his advice, after the experience with the conduit, was rejected. An effort of the engineer to secure actual competition at the second letting revealed the fact that an unwritten law of the local contractors forbade them from interfering with what they called "another man's job." With great difficulty a single competitive bid was obtained at about 10% over the engineer's estimate. The gate-house was built under contract with this bidder at the following prices:

Foundation concrete	40 cu. yds. at	$7.00
Excavation	100 " "	1.50
Pipe laying	120 ft.	2.00
Building, lump sum		3,270.00

The total payment was $3,680, and a fair profit was realized. The engineer's estimate was $3,621. The well of the gate-house was of vitrified paving brick, while the house over the well is of ordinary hard-burned building brick.

THE TOMHANNOCK DIVISION.

The Tomhannock division of the new supply work was by far the most important. Plans for the [illegible] were under way while the Quackenkill division was being built. The final plans called for an earth dam, with concrete core-wall, a separate spillway dam of concrete and a tunnel and pipe conduit, besides much road and bridge work.

The site chosen for the dam is unusually favorable for the purpose. The valley narrows up to a width of 150 ft. at ordinary valley surface level, and has steep side slopes spreading to a width of only about 410 ft. at an elevation of 70 ft. above the creek. On one side is a knoll and back of this is a saddle, in which the spillway is built entirely separate from the dam. Moreover, the soil is thin, and underlaid with very compact clay and gravel, constituting hardpan, which extends down for about 150 ft. to the bed-rock, which is Hudson River shale. The site would have been even more favorable if the adjacent ground on either side had been about 10 ft. higher or the upper end of the valley about 10 ft. lower, but the situation is excellent as it is. The bed of the stream at the dam-site is 334 ft. above the water. The crest of the dam was fixed at 401 ft., and the crest of the spillway at 390 ft.

The general design of the dam is shown by Fig. 4. Fig. 5 is a general view of the site of the dam and reservoir, and Fig. 6 is a nearer view of the dam-site. A public road will lie across the dam. The following features of the dam may be noted: The core-wall extends not less than 13 ft. into the hardpan foundation, with a tongue 3 ft. wide extending 2 ft. further. The front slope is paved with small stone riprap to elevation 370 ft. from where the paving is of heavy stone carefully laid. The paving is capped with a concrete curb carrying a gas-pipe rail. The riprap is curved out at the bottom. An unusually thick portion of clay and gravel, what is usually

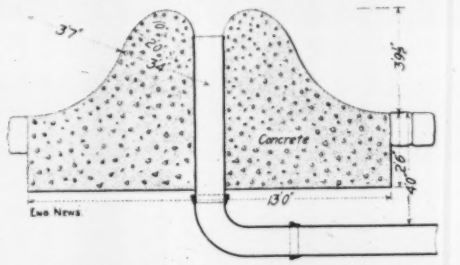

Fig. 3. Section of Outlet of Quackenkill Conduit Into Brunswick Lake.

called puddle, is placed in front of the core-wall. Most excellent material was available for the entire earth portion of the dam, but was so compact that it was with difficulty excavated and broken sufficiently fine to pack well in the dam. Material for concrete and riprap was not so plenty. The only rock available in the vicinity was field stone, and this was not abundant. A comparatively poor quality of gravel was found in large quantities about a mile from the dam and in smaller quantities near by. The specifications called for a 1:3:5 broken stone concrete, but permitted the use of gravel in proportions to be determined by the commissioner of public works, under whose direction all work was done. The proportions finally determined upon were 1:4 and 1:5, according to the character of the gravel, which varied. The proportions were determined by a water test, and a slight excess of cement used, supposedly enough to make the gravel concrete about equal the broken stone concrete.

A culvert, shown in Fig. 4 and also in the view, Fig. 6, was built through the dam to carry the water of the stream during construction. One of the interesting questions that has arisen is as to the closing of this culvert. The original plan was to close it permanently on the completion of the dam, which was to be in one season after closing the creek bed. The culvert was not designed to take a spring freshet. Entrance to the culvert is through two 36-in. sluice gates in a

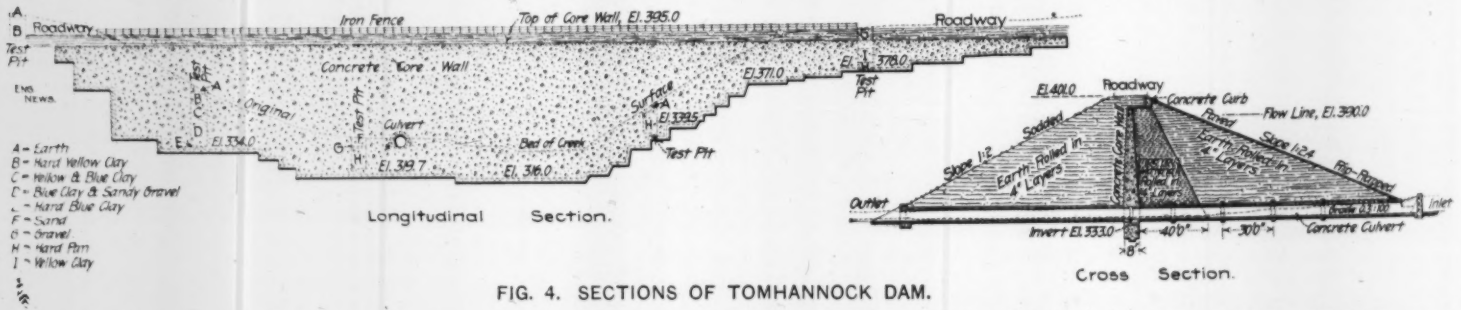

FIG. 4. SECTIONS OF TOMHANNOCK DAM.

head wall built across the upper end of the culvert. These gates were expected to take all ordinary flow of the stream, and about 10 ft. of the crown of the culvert back of the head wall was omitted to admit the water of the greater storms, when the flow should become so great as to exceed the capacity of the gates. The object of putting the gates in at all was the more easily to control the flow when closing the culvert. Only once during the construction period did the flow exceed the capacity of the gates. This was during the great storm of October, 1903. Where the culvert intersects the core-wall, a groove 2 ft. wide by 2 ft. deep was left throughout the inner circumference of the culvert, and an opening was carried through the core-wall from the top of this groove to the top of the core-wall. To close the culvert it was proposed at time of low [illegible] the stream to insert a pipe in one of the [illegible] openings in the head wall, to extend the [illegible] back of the 10-ft. open space in the [illegible] close the other opening by the sluice gate [illegible] all the water should pass through the [illegible] build a bulkhead across the culvert back [illegible] 10-ft. opening, to fill the culvert betw[illegible] bulkhead and head wall solid with con[illegible] close the sluice gate leading to the pip[illegible] the pipe and culvert from below with gra[illegible] ly to the core-wall, and then with concre[illegible] point some distance beyond the core-wall [illegible] ing a tight joint at the core-wall by pour[illegible] mortar down the opening in the core-wa[illegible] lower end of the culvert could be left [illegible] filled, but should perhaps be filled to av[illegible] possibility of future rupture.

The interesting question that has arisen [illegible] as to whether a permanent opening should [illegible] left through the dam. If so, it can be done by [illegible] one or two lines of pipe through the culvert, put-ting gates on their lower ends, and filling the remainder of the culvert solid with concrete, or concrete and gravel. The opinions of engineers who have looked carefully into the matter differ; the majority, perhaps, favoring a permanent opening. The argument for leaving an opening is, of course, the possible future necessity of drawing down or emptying the reservoir for repairs, cleaning, or the removal of bottom stagnant water. One advocate of a permanent opening considered it advisable in order that the very dregs might be available for use, the outlet to the conduit line being some 15 or 20 ft. above the bottom of the culvert. The arguments against a permanent opening are the following: (1) Because of its great size, and the consequent time required to empty and again fill it, it will never be practicable to empty the reservoir after it is once put in service. (2) The many large springs in the bed of the reservoir and its great depth and surface area will cause it in a short time to be of the nature of a natural lake, tapped at the several levels corresponding to the gate openings in the outlet chamber. (3) Since the dam is about a mile down stream from the outlet to the city mains, little good could ever come from an attempt to draw off bottom water at the dam. (4) Any opening in the dam, although it may exist for many years without repair, is of necessity of less permanence than the dam itself, and is hence unwarranted unless its existence will meet some practically possible necessity, and the original designer thought it more probable that the permanent opening might at some future time be the cause of the destruction of the dam than that such an opening would be found necessary for drawing down the water. (5) As to the using of the last drop in the reservoir, the argument is that such a thing would be highly improper. Such use in a system of this kind would mean an immediate famine.

Another interesting question not yet decided is as to the treatment of the bottom of the lake. Stripping the soil, which would double the cost of the entire system, has not been contemplated by the designing engineer. The bottom is not muck, but for the most part is a clean, gravelly soil under cultivation. A few mucky places of small area exist, and should be covered or the muck removed. The contractor for the work of reservoir building has agitated the question of soil removal with the expectation of securing additional work. The present engineer, Mr. E. L. Grimes, has reported that stripping is desirable if the city can afford it, but advises that filtration should be first

nsidered. The designing engineer believed that it is far from clear that the removal of the soil from the bottom of so large a lake, almost the whole of which bottom is devoid of marsh, peat, or offensive muck, will greatly improve the quality of the surface water drained from miles of cultivated, fertilized fields, from forests and considerable areas of marsh and swamp land, and

FIG. 5. VIEW OF SITE OF TOMHANNOCK DAM AND RESERVOIR.

(The most distant line of hills is about 6½ miles away; the reservoir will extend towards those hills for a distance of five miles.)

stored in the reservoir. There are many old mill ponds in the vicinity of Troy that yield water of excellent quality, and whose bottoms were never cleaned. They are ponds of considerable area, and are still full of stumps that show even above the water. This experience seems to be directly contrary to that at Boston and elsewhere, but is believed to be in accord with experience in many places. But even granting that the uncleaned bottom will foul the water at certain seasons, almost any system of filtration or purification would be less costly for the city of Troy than the stripping of the bottom, which would accomplish absolutely nothing in the way of the removal of disease germs, should they ever appear in the reservoir, a result that would be practically entirely accomplished by any good system of filtration. And filtration will ultimately be demanded by all cities supplied with surface water It is doubtful if either stripping or filtration is immediately necessary.

Water for use in Troy is drawn from the reservoir through a tunnel about 5,900-ft. long, and a riveted steel and cast-iron conduit about 50,000 ft. long. Investigation showed that the water could be delivered from the Tomhannock reservoir to the low-service storage reservoir, now supplied by pumps, at the rate of 15,000,000 gallons in 24 hours through a 30-in. cast-iron pipe. The pumping system force main already in use was such a pipe extending for about 15,000 ft. of the distance to be covered, which distance could not be greatly lessened by adopting an entirely different location. The only other practical location was one which from the nature of the topography required delivery at an elevation sufficient to supply the middle service. This route, while a little shorter than that by way of the existing force main, would so reduce the head as to require a 36-in. cast-iron main for the delivery of 15,000,000 gallons daily. Estimates of cost proved greatly in favor of the force main route, and, the middle service being well supplied from the new Quackenkill division, the 30-in. line was adopted.

The tunnel is driven wholly through Hudson River shale, for the most part very compact. The projected section was 4 ft. wide by 6½ ft. high-the roof being a semi-circular arch and the floor segmental. Bidders were informed that they would not be required to adhere strictly to the projected section if it should prove more economical to make it wider and lower, provided the section adopted should be uniform and of area equal to that of the projected section. The excavated tunnel is of various sections, nowhere less than the proposed area, and in general of an area from 50 to 100% in excess of that proposed. At one point, for a distance of about 15 ft., the surface of the rock was reached in the roof and the overlying clay penetrated. The western or outer end of the tunnel is about 11 ft. wide for about 410 ft., in order to provide room for laying two lines of conduit pipe, which are carried thus far into the tunnel. At the inner end of this wide section there is a shaft and a bulkhead wall of concrete, in which the conduit lines will terminate in two reducers. The entrance to the conduits is governed by sluice gates operated from a gate-house built over the shaft. Entrance to the tunnel from the lake side is through a gate chamber, approached by a long open canal or ditch in the bottom of the reservoir. The gate-house is provided with two sets of gates, three in a set, controlling, through two different chambers, the drawing of water at three different levels. The chambers are in duplicate to provide for emergencies. Openings in the outer wall are covered with permanent coarse bronze screens. Stop-plank grooves are provided for emergency use. The two outer chambers, into which water enters freely at all levels, are separated from the tunnel entrance by a partition wall, in which are the openings covered by the gates, and at the back of which are stop-plank grooves to provide for repair of the gates. The walls of the chambers are to be of concrete and the house above of brick. Doors and guard rails are provided over the openings in the outer wall to permit raking the screens, which have no cross bars to interfere. No fine screens are used, as the water is again screened in the gate chambers of the city reservoirs.

The contract for the tunnel work was let to P. H. Harrison & Sons Co., at the following prices, the specifications providing that $7 per cu. yd. would be paid for concrete used as tunnel lining, should any be needed, which was stated to be improbable:

Earth excavation in tunnel approach, including hardpan	17,200	cu. yds. at	$0.90
Rock excavation:			
In tunnel approach	1,700	" "	2.00
In tunnel and shafts	6,600	" "	6.50
In gate chamber	525	" "	3.00
Earth in gate chamber and shafts	920	" "	1.00
Concrete lining in tunnel	36	" "	7.00
Concrete in gate chamber and shafts	1,115	" "	7.00
Bronze screens in place	5,000	lbs.	.30
Iron in ladders	570	"	.05
Iron in floors	1,550	"	.06
Eastern gate-house over gate chamber	lump		700.00
Western gate-house over shaft	lump		500.00
Roofs over shafts	3	lump for all	75.00
36-in. sluice gates with stems, braces and standard, set in place	8	lump for all	2,000.00

The contractor lost money on the work. There appeared an opportunity to recover this loss if an order to line the tunnel throughout could be secured; for, although the price for lining concrete was small, if the specifications should be rigidly adhered to, the greater portion of the necessary extra excavation was already done, and a small amount of work would make a large sum payable at an early day. The contractor sought such an order, and it was given against the advice of the consulting engineer, who at once resigned.* The specifications were then modified so as to make the work less costly, by providing that the large excess excavations might be filled with large stone bedded in concrete, instead of wholly concrete, as originally specified, and the work of lining has since progressed. This work, if carried out in full, will more than double the cost of the tunnel, and will delay the completion of the whole system one year. The ordering of

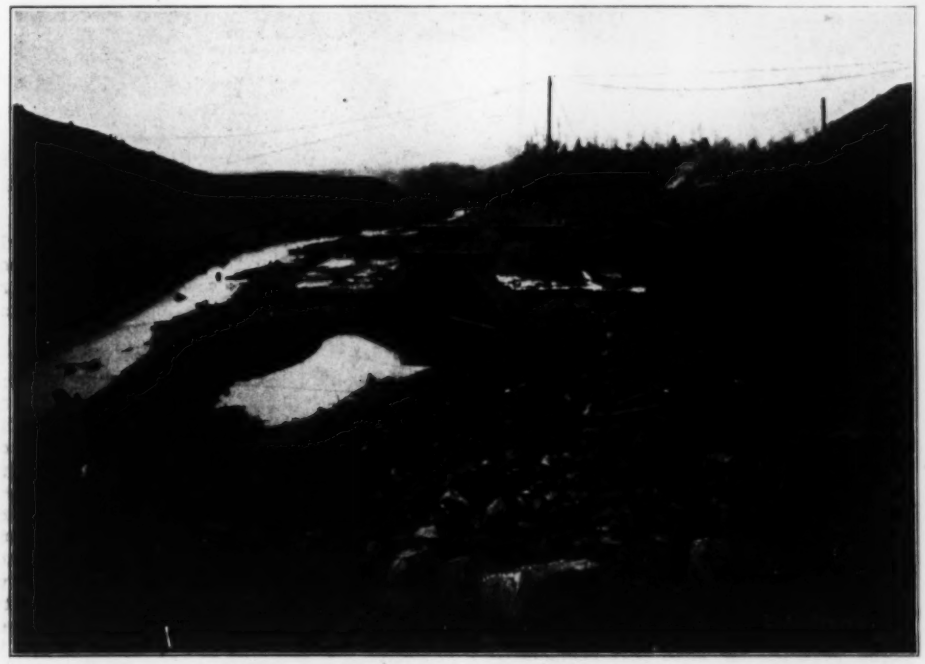

FIG. 6. TOMHANNOCK DAM SITE, LOOKING UP STREAM.

(The culvert for use during construction had been completed and about 50 ft. of the core-wall had been built to the height of the culvert.)

*This matter was discussed at length in Engineering News, Sept. 3, 1903.

this work assisted to defeat the political party responsible for it at the fall election in 1903, and there is some possibility that the tunnel will not be wholly lined. About 600 ft. of the tunnel remain to be driven, and about 4,700 ft. to be lined. Payment has, however, been made for the extra excavation necessary for the lining throughout the portion excavated.

Alternate bids for cast-iron and riveted steel pipe for the conduit were invited. It was provided that 33-in. steel pipe should be laid to give carrying capacity certainly equal to that of a 30-in. cast-iron pipe. It has been claimed that there was no real competition in the bidding, and there were circumstances pointing to a pool. A considerable percentage would have been allowed

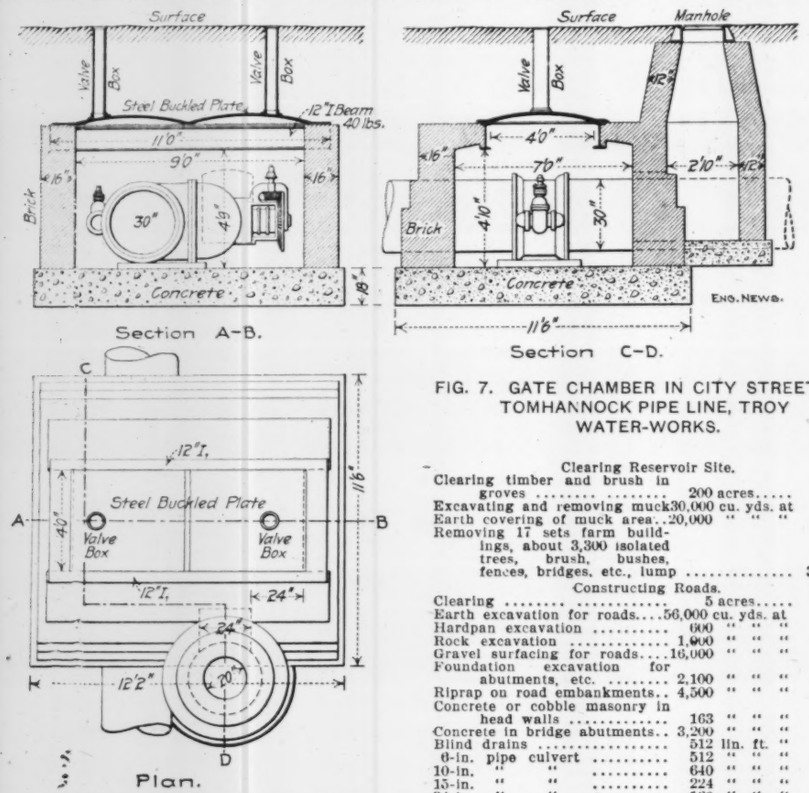

FIG. 7. GATE CHAMBER IN CITY STREET ON TOMHANNOCK PIPE LINE, TROY WATER-WORKS.

in favor of cast-iron pipe, but the only bid for laying cast-iron pipe that approached the low steel bid was from a bidder thought to be, whether justly or not, unable to complete the work properly and on time. The contract for furnishing and laying 33-in. riveted steel pipe, including all appurtenances, was therefore let at the following prices per foot: In rock, 3,100 ft., at $6.80; in earth, 32,200 ft. at $7.40.

The delay in the completion of the tunnel prevented the entire completion of the pipe line, but so far as it was possible to finish the work was done on time by the contractor, the T. A. Gillespie Co. There were some deep excavations, varying from 20 to 30 ft. A blow-off was placed in each sag in the grade line, and a gate and air valve at each summit. Where valves occur in the city streets they are placed under the cross walks, with chambers and valve boxes, as shown in Fig. 7.

The reservoir construction included the building of about 7 miles of country roads. The roads replaced were for the most part comparatively poor dirt roads. The city has built excellent gravel roads in place of these.

The reservoir construction was let to The McDonough Construction Co., C. L. Johnson, engineer, at the following prices:

Dam and spillway.	Quantities.	Unit price.*
Clearing and grubbing	3 acres	$200.00
Excavation:		
Surface soil beneath the dam	9,100 cu. yds. at	.40
Earth in trenches at the dam	2,400 " " "	.40
Hard material in trenches at the dam	2,350 " " "	2.00
Hard material in spillway	2,000 " " "	2.00
Earth in the spillway	38,000 " " "	.40
Embankment in dam or spillway:		
Previously paid for as excavation	14,820 " " "	.22
Hard material excavated for this purpose	26,750 " " "	1.00
Earth excavated for this purpose	77,140 " " "	.35
Concrete: In core wall	6,400 " " "	6.00
In culvert	700 " " "	7.00
In curb on main dam and all spillway concrete	4,835 " " "	6.00
Riprap on dam	1,020 " " "	1.00
Paving on dam	2,810 sq. " "	1.50
Brick paving in spillway, including concrete	3,535 " " "	2.50
Masonry in over fall of spillway	95 cu. " "	12.00
Bridge over spillway in place		1,000.00
Railing on dam	460 lin. ft., at	1.00
Gutters at dam	370 " " "	1.00
Sodding and seeding	5,020 sq. yds. at	.20
Caring for water		1,000.00
36-in. sluice gates in place	2 lump sum.	600.00

Clearing Reservoir Site.		
Clearing timber and brush in groves	200 acres	$25.00
Excavating and removing muck	30,000 cu. yds. at	.50
Earth covering of muck area	20,000 " " "	.40
Removing 17 sets farm buildings, about 3,300 isolated trees, brush, bushes, fences, bridges, etc., lump		3,000.00
Constructing Roads.		
Clearing	5 acres	$30.00
Earth excavation for roads	56,000 cu. yds. at	.28
Hardpan excavation	600 " " "	1.00
Rock excavation	1,000 " " "	1.50
Gravel surfacing for roads	16,000 " " "	.65
Foundation excavation for abutments, etc.	2,100 " " "	.40
Riprap on road embankments	4,500 " " "	1.00
Concrete or cobble masonry in head walls	163 " " "	5.50
Concrete in bridge abutments	3,200 " " "	6.00
Blind drains	512 lin. ft. "	.20
6-in. pipe culvert	512 " " "	.30
10-in. " "	640 " " "	.55
15-in. " "	224 " " "	.75
24-in. " "	160 " " "	2.50
Steel for bridges in place	76,000 lbs	.06
Lumber for bridges, in place	21,000 ft., B.M.	35.00

*Unless otherwise stated.

As the road location was not completed when the specifications were drawn and the estimates made, the quantities varied considerably from those in the estimate, the bridging being much reduced and the earthwork considerably increased.

All specifications for the Tomhannock division called for completion by Nov. 1, 1903. At that date very little remained to be done that could be done with the tunnel incomplete. It is expected that the tunnel will be completed during the summer of 1904, that the gates in the dam may be closed some time in the fall, and water used some time during the winter of 1904-5. A proper progress of the tunnel, even though it were incomplete, would have permitted closing the culvert through the dam in the fall of 1903. As it is, this culvert was left open and passed a spring freshet, which it was not designed to do. The outcome was watched with much interest, but the usual spring floods did not occur, and no damage was done. The water rose some 18 or 20 ft. over the culvert.

The work is now carried on under the direction of a Municipal Improvements Commission, composed of the Commissioner of Public Works, the Comptroller, and the President of the Common Council, with Mr. E. L. Grimes, M. Am. Soc. C. E., in charge as chief engineer. Mr. James Burden, M. Am. Soc. C. E., and Mr. George M. Bull, C. E., are the principal assistant engineers.

Since the foregoing was written, differences have arisen in the commission, all Democrats, two of them being opposed to the third, who represents the democratic mayor. As a result the mayor sought the help of the local republican organization to secure additional legislation, which again changed the governing body, making it include the mayor, corporation counsel, commissioner of public works, comptroller and president of the common council.

A contest in the courts has resulted in a decision declaring unconstitutional the law providing for the increased commission and restoring the former commission to power. This decision has been appealed and the end is not yet. Messrs. Burden & Bull have retired from the work, the Harrison contract for the tunnel has been assigned to the Powers-Mansfield Co., the tunnel materially progressed, and the reservoir practically completed.

CHLORINE IN METALLURGY.*

By James Swinburne.†

The essense of metallurgy, as practiced for thousands of years, is the reduction of the oxide of the coveted metals with carbon, as such or as monoxide. Some metals, notably iron, exist in nature ready as oxide, but most of the others are found as sulphides. The sulphides are, therefore, roasted to convert them into oxides, and the oxides are reduced with carbon. Modern metallurgy broadly consists of the reduction of oxides to the metallic state.

The process I have the honor of bringing before you depends on the action of chlorine. Chlorine has been used in metallurgy before for attacking metallic gold, and salt has been employed for "chloridizing" roasting. The present process is, however, a new departure, of quite a different kind, and really a new form of metallurgy calculated to displace the oxidation and reduction processes now in use to a great extent. How far the replacement will take place depends eventually on economy only.

The principle of the process is treating sulphide ores, without previous roasting, with chlorine, so as to form chlorides of the metals, the sulphur being liberated as such. The chlorides are then electrolyzed, yielding metals and recovering the chlorine. The chlorine thus goes round and round; and the process in its simplest form is analogous to separating the sulphur from the metals electrically, and changing the ore, at the mere expense of electrical energy, into its component metals and sulphur. This can in fact be actually done. In one of my first patents there is a description of electrolyzing a bath of, for instance, zinc chloride and zinc sulphide, with carbon anodes and fused zinc cathode. This gives off zinc at the cathode, and pure sulphur, not chlorine, at the anode. This simple method is not applicable to many ores on account of gangue, iron and other metals. It is mentioned to give a clear idea of the essence of the process.

In practice there are further modifications. The process naturally gives the best commercial return on ores that are refractory to other treatment; and complex ores yield mixtures of chlorides and gangue which could not be electrolyzed straight off without intermediate treatment. The intermediate treatment is always simple chemically, and consists in removing the gangue, and substituting zinc for the other metals one after the other till there is nothing but chloride of zinc left. This chloride of zinc is then electrolyzed and the zinc and chlorine recovered. If there was no zinc in the ore, all the zinc obtained is used up again; but if there was zinc in the ore it is sold as zinc.

The action of chlorine on sulphides is generally very vigorous, and enough heat is generated to keep the mass hot. The transformer is something like a small cupola. It is an iron vessel lined with firebrick, and it contains mixed chlorides fused carrying the gangue and ore. The ore is run in at the top continuously and chlorine is pumped in at the bottom; sulphur coming off and passing over into a condensing chamber. There is no difficulty about pumping chlorine. Iron cylinders, pistons and valves are employed, and, as is well known, though not fully realized, dry chlorine, such as that from the electrolysis of fused chlorides, is a very harmless gas.

The transformer is tapped at intervals, and the mixed chloride and gangue run into water. Broken Hill slimes, a waste product daily becoming more mountainous, have been chosen to work upon. They contain zinc, lead, iron, silver, manganese, sulphur and gangue. The gangue and lead chloride come out together, and the lead chloride is separated, the silver extracted, and the lead chloride electrolyzed. The soluble chlorides are treated with chlorine, to get ferrous into ferric chloride, and the iron precipitated with zinc oxide or calamine. The manganese is got out separately or with the iron in a similar way. The zinc chloride is then boiled down and electrolyzed.

*Abstract of a paper read before the International Electrical Congress at St. Louis, September 12 to 16, 1904.

†Consulting Electrical Engineer, 82 Victoria St., London, England.

The electrolysis vat is simply an iron case lined with fire brick, and is kept hot by the excess of the electric over the chemical energy.

The history of the process is simple. The first patents were in 1897, and the process was tried in the laboratory and everything worked well. It was then tried on a pound scale and worked. A plant was taken in Milton, and large scale experiments on electrolysis and handling of chlorine were carried out. A 3,000-ampere electrolytic vat was run continuously for three months. Facilities were wanting there. Mr. A. J. Smith, the general manager of the Castner-Kellner Co., saw a chance of a future in the process, and the company made arrangements for us to put down an experimental plant next door to its works. This was done and the transforming was proved on a large scale.

We have repeatedly learned from the technical journals that the chlorine reaction does not take place, and that fused zinc chloride cannot be electrolyzed. In fact people have proved it with test tubes. The Castner-Kellner Co., however, was able to investigate the working of the process, and to inspect the transformer consuming at the rate of 30 tons a week. It was well enough satisfied with the results to arrange to take the works over, acquiring a license to make chloride of zinc. It thus uses the whole process except the electrolysis, as they have a supply of chlorine from the soda works. It will run a 10,000-ampere vat for demonstration, but otherwise will sell every metal but zinc, the zinc being sold as chloride. The only difference in the process is that zinc chloride must be much more highly refined for the market than for electrolysis, as a trace of manganese, for example, would spoil the color, but would do no harm in electrolysis. The chlorine is also damp, and has to be dried before being pumped.

A good deal of work has been done recently on the treatment of ores with little metal content, such as copper ores running under 3%, and copper nickel and cobalt ores. These modifications have only been tried on the small scale, and so it is too soon to speak yet, but apparently low grade copper, and nickel, cobalt and of course their mixtures, and copper zinc ores of low content will prove amenable.

THE NEW CHARLES RIVER DAM AND BASIN AT BOSTON, MASS.

By J. Albert Holmes.*

Plans are being matured and it is hoped that construction will begin this fall on a dam across the Charles River, near its junction with Boston Harbor, at Boston, Mass.

Briefly the conditions to be met in the construction of a dam at the point selected are these: The lower portion of the Charles is a tidal estuary into which is discharged the upland flow from 217 sq. miles; the mean range of tide is nearly 10 ft., with a maximum rise of about 15 ft., affecting the river for a distance of ten miles above the harbor.

It is proposed to construct a dam sufficiently high to shut out all tides. This will convert the area above into a fresh water basin, similar to the Alster Basin at Hamburg, Germany, or the Schuylkill at Philadelphia.

As shown by the accompanying map, the original area of the estuary has been greatly reduced by the construction of tide mill dams in several of its bays, followed by the filling of the enclosed areas, together with many acres outside the dams, until only 40% of the former water surface remains. The largest project of this kind was the building of a mill dam on the line of Beacon St., and its subsequent filling, making the land in that portion of the city known as the Back Bay. In connection with this dam, a dam was also proposed across the Charles at about the site of the present Harvard Bridge. Its construction was not undertaken. This was in 1814.

The project for a dam and water park has been discussed from time to time since 1859. In 1894 the matter was investigated and favorably reported upon by a joint board consisting of the Metropolitan Park Commission and the State Board of Health. This report was referred to the State Harbor & Land Commission, with directions to inquire into the construction of a dam and lock in the tidal basin of the Charles River, as proposed by the joint board, "with special reference to interference with tide water and its effect upon the Harbor of Boston."

The data at hand were insufficient to determine the effect and possible injury to the channels of the harbor by the cutting off of so large a volume of tide water, "and in view of the incalculable injury which might ensue," the commission was "unable to report in favor" of the project.

In 1898 the Metropolitan Park Commission was directed to construct a dam, with locks, across the Charles at St. Mary's St. This is at the head of the Basin proper, or at the head of the broad portion of the estuary. A dam at this point would affect only about one-third of the tidal flow. No attempt was made to construct the dam.

A committee was appointed in 1901 to "investigate and report upon the feasibility and desirability of constructing and maintaining a dam across the Charles River." A careful and exhaustive examination was made by this committee of all questions relating to the construction of a dam. The recommendation was made that a dam sufficiently high to keep out all tides be built and that a fresh water basin be maintained at a permanent level about 2 ft. below mean high tide. The site recommended, which was adopted by the commission appointed in 1903 to build the dam, is that occupied at present by Craigie's or Canal Bridge, a pile structure originally built in 1808, rebuilt and repaired several times, and now requiring to be replaced by more permanent construction. The roadway which will take the place of the present bridge will be combined with the dam.

The dam will be a solid earth fill, varying from about 200 to nearly 500 ft. in width, with a maximum fill of 50 ft., retained above mean low water by stone and concrete walls, and below low water by riprapped slopes. The wall on the basin side is irregular in line. That on the harbor side is straight and about 1,300 ft. long. Near the westerly or Cambridge end there will be sluices to discharge the surplus water from the basin into the harbor at low tide. A small boat lock will also be located at this end.

At the easterly or Boston end will be located the lock for large vessels. This will be a concrete structure on a pile foundation, 350 ft. in length between gates, 45 ft. wide, with 17 ft. of water on the lower sill at mean low tide. The total length of the lock structure will be about 492 ft.

The roadway, 85 ft. wide, is to be carried on the solid fill of the dam. It will be parallel with and adjacent to the harbor wall and will cross the lock on a drawbridge.

The surface of the dam not occupied by the roadway and lock, about 6½ acres, will be laid out as a park, which will connect with the park areas already built along the shores of the basin.

In connection with the building of the dam and lock the commission is required to construct conduits along the margin of the basin, both in Cambridge and Boston, to deliver the storm water from large existing drains, which discharge above the site of the dam at present, to a point just below the dam. The intercepting drain on the Boston side will be about 9,500 ft. long, discharging below low water through two 60-in. cast-iron conduits, each 130 ft. long. The interceptor on the Cambridge side will be about 2,100 ft. long, including 400 ft. of siphon and 150 ft. of submerged outfall, both of 60-in. cast-iron pipe.

Channels to two canals connected with the basin and the canals themselves, one 3,400 ft. long and the other 2,000 ft. long, are to be dredged and their walls and bulkheads reinforced.

The consent of the Secretary of War to the occupation of the river between harbor lines has been given, with certain conditions, three of which are:

(1) That detailed plans for the lock and dam, and of all channels to be dredged outside established harbor lines, shall be submitted to the Secretary of War, and that the work be not begun until such plans have received his approval.

(2) That the Charles River Basin Commission, or its successors, shall operate the lock, at its own expense, as a free navigable waterway of the United States, subject to such regulation as the Secretary of War may promulgate.

(3) That the emptying of the basin shall be subject to regulation by the Secretary of War.

The basin formed by the dam will have a length of eight miles and will be nearly a half mile wide at its widest portion, with a total water surface of about 830 acres.

All but 1½ miles of its nearly 17½ miles of shore is in public ownership, and is either already laid out in pleasure grounds and drives or is planned to be so used.

The basin forms the center of, and its bordering drives make connections with, the whole great system of Metropolitan Parks and Parkways.

The official title of the body formed to construct the dam and accessories is the Charles River Basin Commission. The members of the commission are as follows: Henry S. Pritchett, Henry D. Yerxa and Joshua B. Holden. Mr. Hiram A. Miller, M. Am. Soc. C. E., is chief engineer; Mr. Frederic P. Stearns, M. Am. Soc. C. E., is consulting engineer, and Mr. Wm. S. Youngman is secretary to the commission.

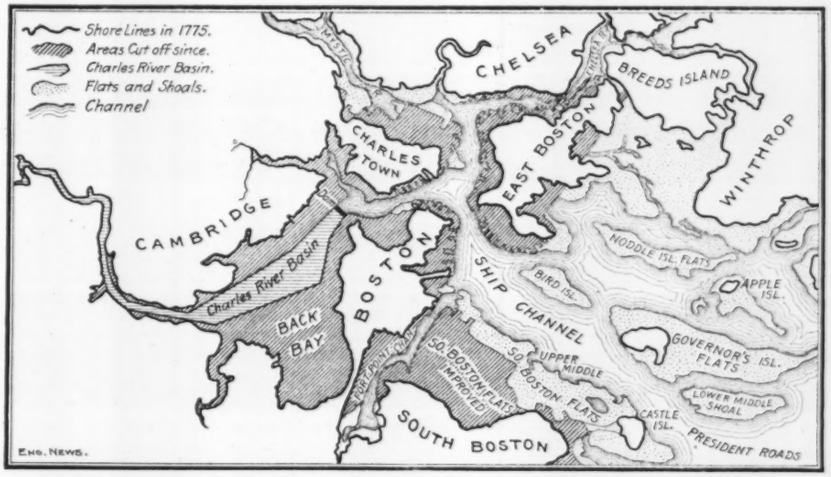

FIG. 1. MAP SHOWING THE LOCATION OF THE CHARLES RIVER DAM AND BASIN.

(The map also shows the encroachments on the natural tidal waters of Boston Harbor, mostly since surveys of 1835 and wholly since Des Barres map of 1775. The map is reproduced from one included in the "Report of the Committee on Charles River Dam, Boston, 1903.)

REINFORCED CONCRETE TIES, ULSTER & DELAWARE RY.

The latest design of reinforced concrete railway tie to call for attention is illustrated in the accompanying cuts. This form of tie is being experimented with on the Ulster & Delaware R. R., and we are indebted to Mr. R. Sullivan, Road Master, of that railway for the following description:

The accompanying drawings and views from photographs show the construction of a new design of reinforced concrete railway tie. Fig. 1 is a drawing showing the dimensions and form of the tie; Fig. 2 shows the mold for casting the ties, and Fig. 3 shows a stretch of track laid with the cast ties.

As these ties are but an experiment and have not been in the track yet for any length of time, it, of course, re-

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melts to be seen what will be the effect on them of ice and snow, heaving by frost, and general wear and tear in roadbed. In the view, Fig. 2, the impression left by the grain of the wooden forms on the cement can be so plainly seen that at first glance the track ties might almost be mistaken for wooden ties. The concrete before being shoveled into the forms and around the angle iron reinforcement was mixed tolerably wet, shovel-tamped or spaded, and it was found that a mortar facing was not necessary. The proportions of the concrete consisted of 1 part Atlas Portland cement, 2 parts coarse, sharp sand and 4 parts ¾-in. diameter crushed lime rock.

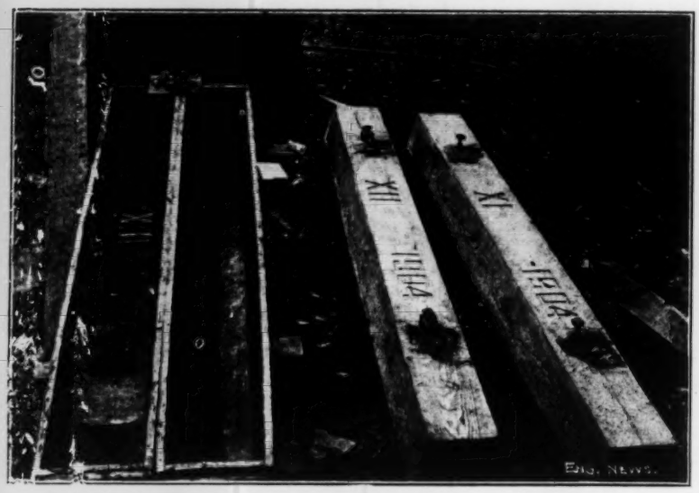


FIG. 2. MOLD FOR CASTING REINFORCED CONCRETE TIE.

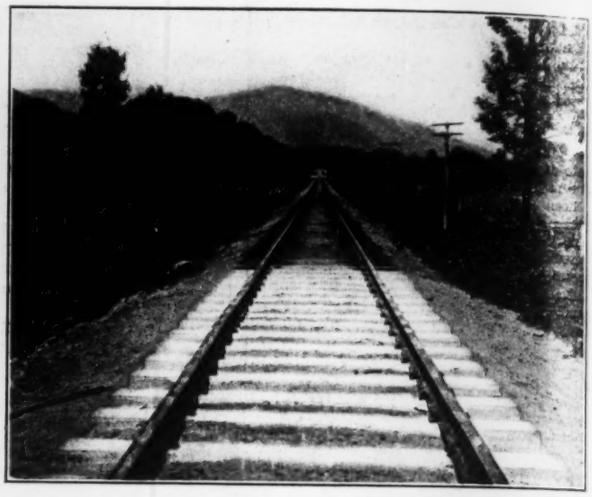


FIG. 3. VIEW OF TRACK LAID WITH REINFORCED CONCRETE TIES.

The cost of making was about 42 cts. per tie, exclusive of the iron used for reinforcing, which was old angle iron picked up about the shop and which varied in size from 2½ ins. × 2½ ins. × 6 ft. long to ⅜-in. × 3½ ins. × 7 ft. 6 ins. long, the ties themselves being 8 ft. in length and weighing about 450 lbs. each.

It may be of interest to know that a tie made of concrete and of very similar design to the above was made in May, 1903, and placed in the track of the Ulster & Delaware R. R. at that time, and now, after over a year's usage, has withstood a very hard winter without showing any signs of deterioration whatever. It might be supposed that the bolt fastenings would work loose, but the nuts and bolts holding this old tie and rail together are now as tight as the day when first put in, and, moreover, have not had any attention since the tie was installed. It may be observed that no provision for shimming has been made for these ties and such ties are somewhat heavy and cumbersome to handle on and off cars and to place in the track, but this may be more than offset if they prove to be lasting. The bolts for fastening heretofore mentioned are ¾-in. × 3½-in., with square heads and nuts passing up and through holes bored and placed correctly in the angle iron, the head of the bolt resting in between the legs of the angle, thus preventing itself from turning when the nuts are tightened up, and also giving a direct pull against the base of rail, only the tie plate intervening.

THROUGH THE LAKE SUPERIOR IRON AND COPPER MINES WITH THE AMERICAN INSTITUTE OF MINING ENGINEERS.

II.

THE VERMILLION AND MESABI MINES.

The special train conveying the members of the Institute for their two days' trip through the Minnesota iron mines, left Duluth late at night and arrived at Ely early in the morning. As soon as breakfast was finished, the visit to the mines was begun, and from this time on for two days the programme was the inspection of one mine after another continuously except during the hours for meals and sleep. As a guide to those who could not make the trip, we have reproduced the accompanying map of the ore fields visited during these two days and the succeeding week. On this map the shaded areas represent the extent and location of the iron ore deposits, and before proceeding, a word as to the extent of these deposits may be interesting.

The Vermillion iron range extends from the vicinity of Tower to and beyond the international boundary, crossing into Canada at the eastern end of Hunters Island. Merchantable ore has been discovered, however, at but two places on this range, at Tower and at Ely, 21 miles east of Tower. At Tower the ore is a dense hard hematite occurring in irregular connected and disconnected lense shaped bodies of jasper intricately enfolded in green schists. The strike is east and west and the dip is approximately vertical with a westerly pitch. The underground workings here are some 4,500 ft. in extent east and west, and have a depth of over 1,000 ft. At Ely the ores differ from those at Tower mainly in their physical structure, being much more broken and friable. The area in which they lie is a trough some two miles long and 1,500 ft. wide. The general dip is nearly vertical, but the pitch at the east end of the trough is west, and at the west end of the trough it is east. The output of ore in 1903 from the Tower and Ely mines was 1,918,584 tons; mining at these localities was begun in 1884, and the initial year's output was 62,122 long tons of ore.

Turning now to the Mesabi range, we find a stretch of ore-bearing rock some 90 miles long, but all of the workable deposits at present known lie between Mesabi Station and Grand Rapids. Here the ore is found in flat beds varying in thickness from a few feet to 500 ft. They are generally located immediately under the glacial drift, but in some places have a cover of taconite, a local name given to the ferruginous chert forming the bulk of the iron ore formation. The cover or overburden varies from practically nothing to some 200 ft., and averages, perhaps, from 60 to 80 ft. The ore is a red, brown and yellow hematite and varies from a firmly compact structure to powder not much different in consistency from sandy loam. Mining on the Mesabi range began in 1892 and in 1903 the output of ore was 13,452,812 long tons.

The mining methods practiced on the Vermillion and Mesabi ranges are distinctly different, and they differ also to some extent at different mines of the same range. As the visitors were shown examples of all of these methods, first one and then another, it may conduce to brevity to describe—very briefly and generally, however—the principal methods without regard at present to the individual mines.

On the Vermillion range deep mining [illegible] alone are employed, the method at Tow[illegible] that known as the overhand stoping meth[illegible] that at Ely as the caving method. At th[illegible] mines, shafts are sunk in the foot wall [illegible] from them drifts or cross-cuts are worke[illegible] the ore vein to the hanging wall. Fr[illegible] cross-cuts, drifts are opened along the s[illegible] the vein. The cross-cuts form levels at 7[illegible] intervals and both they and the drifts are ti[illegible]. The original drifts are then enlarged out[illegible] the timbering and the ore is dumped through chutes rising from the drift sets, and falls into cars which take it to the shaft. As the ore is removed from around the drift sets, the space is filled with rock broken down from cribbed rises in the foot and hanging walls.

At Ely the caving system is employed. Shafts are sunk in either the hanging or foot wall rock or both, and from them drifts are opened across the ore vein. Main drifts are then run along the strike on each side of the ore body. From these main drifts rises are opened upward at 50 ft. intervals, and from these rises cross-drifts are extended across the ore body. These sub-drifts divide the 75 ft. main levels into four sub-levels. Excavation is begun on the topmost sub-level, and the ore is dumped into the rises. As the ore is removed the roof is supported by timbering, and when all the ore has been excavated on this sub-level, the timbers are sliced and the roof allowed to cave. Work is then begun on the next sub-level below, and so on downward.

As is well known, the Mesabi iron mines are notable for the practice of mining the ore with steam shovels from open cuts or pits. This practice is by no means universal, however, as some 50% of the ore is removed by underground methods. It is only fair to state, however, that the tendency now is to abandon underground methods in opening up new mines and even to change some of the present underground workings to open pits.

Steam shovel mining is made possible by conditions peculiar to the Mesabi ore deposits. These deposits are shallow troughs of large horizontal extension; the overburden is drift material, gravel

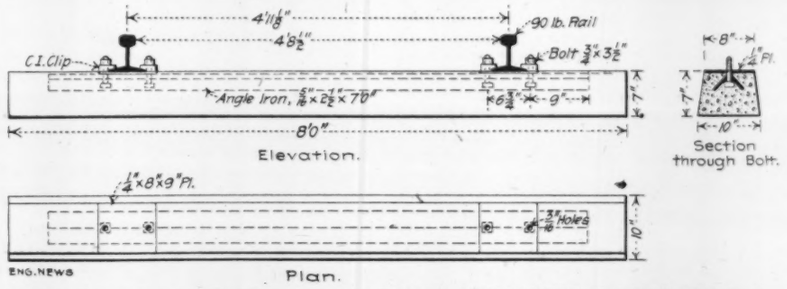
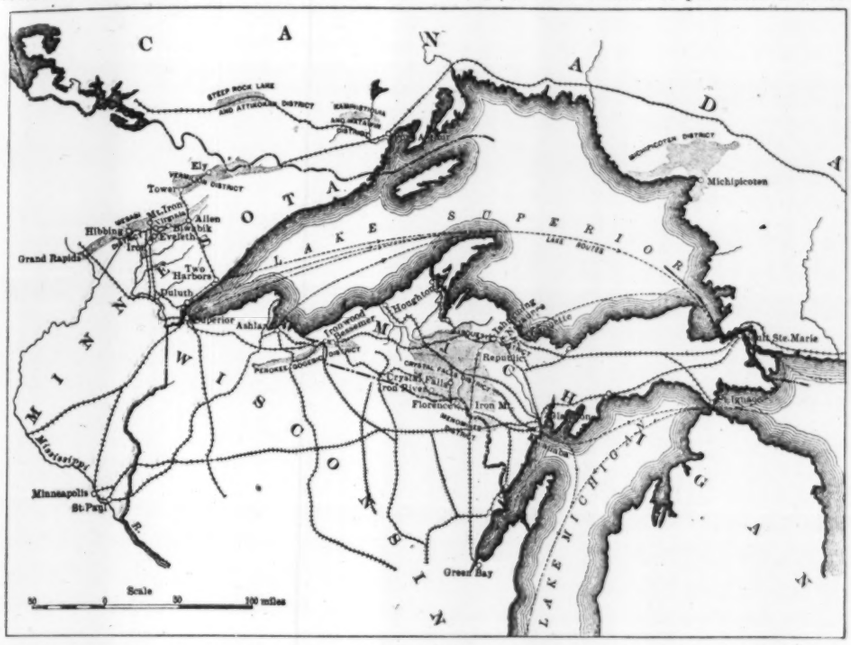


FIG. 1. DETAILS OF REINFORCED CONCRETE TIE, ULSTER & DELAWARE R. R.

and boulders, and the ore is friable and can be readily loosened by black powder blasts. The process of mining is, therefore, simplicity itself. It consists first in removing the overburden by steam shovels and the usual methods of open pit excavations, and then in taking out the ore by exactly similar methods. As a rule, the stripping is done by contract, and several large firms of contractors are engaged exclusively in this work.



SKETCH MAP OF LAKE SUPERIOR REGION, SHOWING IRON DISTRICTS, SHIPPING PORTS, AND TRANSPORTATION LINES.

The contract prices run from 30 to 50 cents per cubic yard, and a contract for stripping from 25 to 40 acres to a depth of 25 ft. is not unusual. "Dinky" engines and 3½-yard cars are used. Two 10-hour shifts are worked. The shovels usually have 2 and 2½-yard dippers. The material ranges from gravel to large boulders and considerable blasting is required to loosen it as well as to break the boulders.

The ore mining proper is done by the mine owners, and they own all the equipment except the cars, which are furnished by the railway companies. These cars are mostly 25-ton wooden cars of box-truss design, but all new equipment consists of 50-ton steel cars, with air brakes and automatic dumps. Generally the shovel works on a 25-ft. face, the ore being first loosened by blasting. Remarkable records are shown by some of these shovels as the following figures will show:

Mine	Burt	Mt. Iron	Mahoning	Stevenson
Date	Aug. 6,'03	Aug. 13 '04	1902	July 28,'04
Make of shovel	Marion	Bucyrus	Bucyrus	Marion
Weight of shovel	93 tons	93 tons	65 tons	100 tons
Capacity of dipper	2¼ yds.	2¼ yds.	1¾ yds.	3 yds.
No. of cars loaded	152	162	.....	201
Gross tons loaded.*	5,096	4,826	4,100	7,109

*One cubic yard weighs about two tons.

It is perhaps worth while to note here that diligent enquiry failed to confirm some of the figures of astounding low cost of steam shovel mining that have become current. A fair estimate appears to show a cost of from 25 to 40 cents per ton.

Nearly as much Mesabi ore is mined by underground methods as by open cut steam shovel work. The two systems of underground mining most practiced are the milling system and the caving and slicing system. In the milling system the ore body is first stripped as in open pit work. A shaft is then sunk in the wall rock and drifts worked into the ore body at base level. From these drifts, up-rises are carried to the surface. The ore is then broken down through these rises and chuted into dump-cars which take it to the shaft. Not more than 10% of the Mesabi output is mined in this manner. In the caving and slicing system the mode of procedure is as follows: A shaft is sunk in the wall rock and a drift is worked into the ore body at base level. The ore body is then divided into a series of sub-levels by means of drifts from 12 to 20 ft. apart vertically and uprises are carried from these drifts to the top of the ore body. The topmost sub-level area is then taken out in slices just wide enough to prevent the roof from caving, the ore being dumped into the up-rises and chuted into tramcars below. As each slice is taken out, the roof above is allowed to cave, and after all the ore is taken from the topmost sub-level, work is begun on the sub-level below. This in turn is worked out and the roof allowed to cave. In brief, the method consists in commencing at the top of the ore and working out each level, dropping the surface as the work goes on.

The mechanical equipment of the Mesabi underground mines is quite simple. It consists merely of the track system in the drifts and of the usual shaft head plant. The latter is light since the depths are not great. The mines carry little water, so that no great amount of pumping plant is required. The haulage underground is done by mules, only one mine being heard of by the writer which had mechanical haulage. This is the Adams mine, with electric haulage. As a rule, the shaft head frames are of wood, steel frames being disfavored because of the short life of the mines. In summer the mined ore is dumped into bins from which the cars are loaded, and in winter it is put into stock piles to be loaded by steam shovel into cars when navigation opens in spring. The stock piles are usually about 40 ft. high and are made by dumping from trestles.

It would be very easy to develop the interesting features of Mesabi mining still further, but this is not the place for that task. Despite all the misinformation that has been spread as to the extent of these mines, allowing for the natural enthusiasm of their promoters and discounting everything told of them by liberal percentages, they still remain the most marvelous iron mines in the world. Just consider for a moment that these mines produced nearly 13,000,000 tons of ore in 1903, that five mines produced more than 1,000,000 tons each, and that this ore was laid down in Cleveland for from $2.75 to $3 per ton, including a railway charge of $0 cts., a lake charge of 75 cts., a royalty of from 25 to 35 cts., all costs of mining and a profit to the operators.

The greater part of the first day's excursion to the iron ranges was spent at the Pioneer mine at Ely. This is one of the deep mines worked by the caving system. Inspection was first made of the new steel shaft head frame, described in Engineering News of Nov. 19, 1903. Many of the party went underground, and much of the time spent at the mines was consumed in this underground trip. Leaving Ely, the party proceeded to the Fayal and Eveleth mines, and then to the Mountain Iron mine of the Mesabi district. In the evening the train proceeded to Hibbing and from that point the party visited the next day the great group of mines clustered around that place and including the great show mine, the Mahoning, of the Mesabi district. A view of this mine was printed in our issue of May 5, 1904. From Hibbing the train proceeded to Duluth, where Sunday was spent by the members as they pleased.

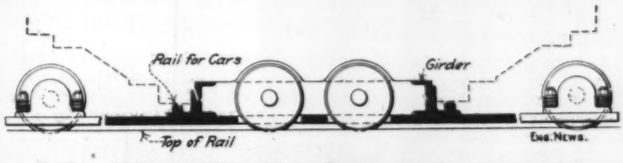


FIG. 1. CROSS-SECTION OF TRANSFER TABLE WITHOUT PIT; WESTERN RAILWAY OF FRANCE.

TRANSFER TABLES WITHOUT PITS AND TRAVELING ON CURVES.

Two transfer tables of peculiar design, and operated by electricity, have been installed by the Western Ry., of France, at Mans and at the terminal station in Paris. The first of these connects the main tracks with the shop tracks, and its path is composed of two tangents united by a curve of 295 ft. radius. The second serves the diverging tracks as they are spread to allow of placing platforms between them, and the transfer table has therefore a curved path with a radius of 590 ft. The main features in each table are that it traverses a curve and requires no pit.

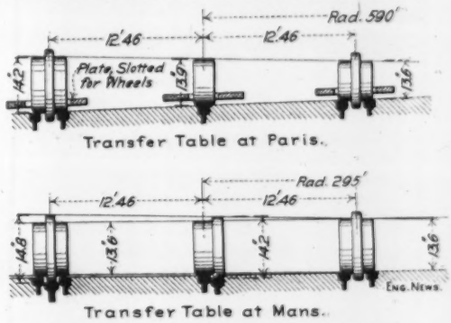


Fig. 2. Arrangement of Wheels for Transfer Tables Traveling on Curves; Western Railway of France.

The length of the table is 30 ft., and it can take cars of 29 ft. wheelbase. Beyond the ends of the fixed rails (which are rectangular bars), are pivoted tongue rails which are inclined so as to lie beside the track rails and so carry the car wheels up to the level of the rails of the table. The table or frame is carried on three rows of wheels 13½ ins. diameter, there being four wheels in each row. These run on independent axles, except that the wheels of the rear row are carried by the driving shaft. The wheels of the middle row of the Paris table have blind tires and run on the head of a tee rail. The wheels of the outer rows have broad tires with middle flanges, the flanges running between the heads of a pair of rails. The transfer table rails are laid with their heads level with those of the track rails. The width c. to c. of flanges is 25 ft. The journals of each row of wheels are carried by bearings on a flat steel plate 2 ins. thick and 20 ins. wide, slotted between the bearings to admit the wheels.

In order to reduce the shocks in crossing the gaps for the flangeways of the main tracks, the plates are suspended from the bearings by spring attachments, as shown in the cross-section, Fig. 1. Across these plates are laid the two longitudinal girders, which are built up of plates and angles, and are strong enough to carry 30-ton cars without deflection. The weight of the table, complete, is 16½ tons.

The table is operated by a direct-current motor, taking current from an overhead circuit by means of a double trolley on the Paris table, and a special contact device on the Mans table. In the former case a 11 KW., 120-volt motor is used, running at 650 to 750 revolutions. The Mans table has a 15 KW., 220-volt motor, running at 900 revolutions. A train of gears drives a shaft, with clutch connections at one end to the shaft of a sprocket wheel with a chain transmitting the power to the axle of the rear set of wheels. The speed of travel is 30 ft. per minute at Paris and 37 ft. per minute at Mans. A hand brake operated by a treadle is applied to a brake wheel on the driven axle. The countershaft can also be connected by a clutch at its other end to the shaft of a winch head or spool on which is a 300-ft. steel cable used for hauling cars on and off the table. The clutches are connected so as to be operated by a single lever, only one being thrown in gear at a time. When the table is adjusted to a track to receive a car it is held in position by vertical locks or plungers engaging with slots in the inner faces of the two rails forming the track for the flanged wheels.

Two men are required: one is in the cab and the other attends to the cable, attaching it to and detaching it from the cars as required. In the cab are located the controller, the clutch lever, the brake treadle, the levers operating the locks, and two levers operating the stop blocks for the car wheels.

In the Paris transfer-table, traveling on a continuous curve of 590 ft. radius, the wheels are of different diameters, calculated to cause the table to travel normally in such a curve, while their axles are also set radial to the curve. The situation at Mans, with a travel on two tangents united by a curve, was a little more complicated. Here the middle wheels have a side flange of smaller height than the flanges of the side wheels. On the curve, extra rails are laid so that the middle wheels and the outer wheels ride on their flanges. The arrangements of the two tables in this respect are shown in Fig. 2. The above description is taken from an article in the "Revue Generale des Chemins de Fer," by M. Pouchucq, Chief Engineer of Rolling Stock of the Western Ry. of France.

REPLACING THE EARTH PORTION OF THE NEW CROTON DAM BY MASONRY.

Rapid progress is now being made in the substitution of masonry for the earth portion of the New Croton Dam. On Oct. 1 the substitute structure had attained a height of about 130 ft. above the bottom of the excavation, and it was expected that Elev. 180, or 16 ft. below the normal water level, will be reached by Dec. 15, 1904. This will permit the reservoir to be partly filled during the coming winter. With that in view, work has been started on closing the water-way and the opening for the construction railway through the base of the main superstructure. The greater part of the main dam, it may be added, has already been completed and the spillway is as nearly finished as will be consistent with the passage of the stream flow if the reservoir is put in service before the dam is completed.

The New Croton Dam will submerge the old Croton Dam and provide storage for 32,000,000,000 gallons of water. As designed, the dam was to be a composite structure; that is, the long spillway and the main dam extending from the spillway nearly across the valley was to be of masonry and beyond the full masonry section the dam was to be continued as a high earth embankment with a masonry core-wall. A number of years ago it was decided to extend the full masonry portion of the dam 110 ft. further towards the south, thus shortening the earth embankment, or that portion of it between the masonry section and the south gate-house, to a length of 290 ft. This earth embankment would have been about 125 ft. high, above the natural surface, and its core-wall would have had a maximum height of about 230 ft. The changes now in progress involve: (1) Removing such of the earth embankment and core-wall as had been built when the construction of this portion of the dam was stopped; (2) excavating disintegrated limestone bared by (1); and (3) continuing the masonry portion of the dam across the valley to the south gate-house. Beyond the gate-house there will be a short length of comparatively low earth embankment and masonry core-wall.*

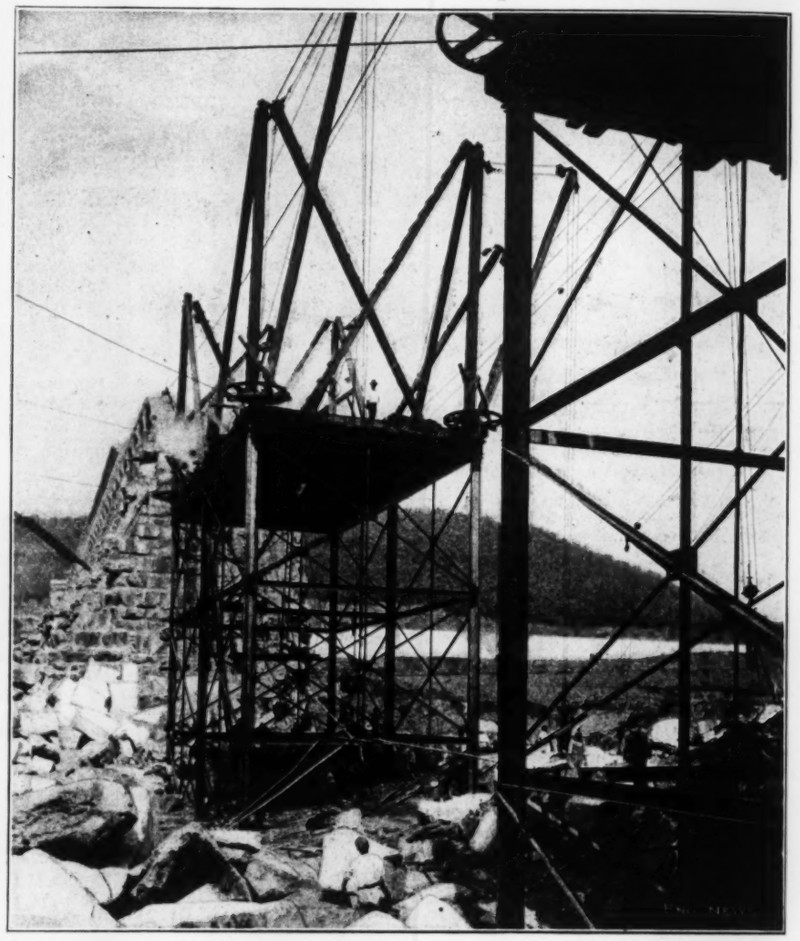
The masonry structure now being erected, in place of the earth dam is similar to the main dam except for (1) a slight increase in thickness, (2) the substitution of concrete for mortar as a bedding material for the cyclopean rubble masonry forming the interior mass of the extension, and (3) the use of rubble instead of coursed stone for the up-stream face below the (Elev. 181).

The increase in thickness is only in the upper or lighter portion of the dam and ranges from 2 ft. at Elev. 150 to 0 at Elev. 99 and Elev. 196. A buttress or pilaster at the end of the old masonry will screen the change in cross-section.

The use of concrete and rubble instead of rubble and mortar is facilitating the new construction, as the huge stones can be placed much more rapidly in concrete than in mortar. The concrete being used is composed of Portland cement, sand and broken granite in the proportion of 1:3:4.

A unique feature of the work, and one largely responsible for the rapid progress being made, is the mounting of derricks on steel towers, as shown by the accompanying view, thus leaving practically the whole top of the dam unencumbered with the derricks and guy ropes that were in use before the towers were erected. The choice seemed to lie between these two methods of handling the material, in view of the concentration of the work in so limited an area.

Two steel towers are used, each 25×50 ft. in plan, with a bull-wheel derrick on each corner, making eight derricks in all. Each derrick is provided with a driving engine. The towers were built 50 ft. in height. Before they were ready for use the masonry had been carried 15 ft. above their bases. The towers are being built into the masonry and their cost will be borne by the city. Steel was used to prevent any question as to the possible dangers of embedding wood in the dam. The steel towers were erected by the Terry & Tench Construction Co., of New York City.



STEEL TOWERS FOR MOUNTING DERRICKS AT THE NEW CROTON DAM.

(On the left, the completed portion of the main dam is shown. In the middle distance may be seen the long overfall wall for the spillway, with a gap left in its center.)

The masonry surrounding the towers is built up in advance of that on the space enclosed by the towers. When the masonry level in the latter space is to be raised, large stones are swung by the derricks to the edge of the enclosure, then rolled down and embedded in the concrete. In the most inaccessible places an extra number of one and two-man stone were used.

The derricks can remain in their present position until the masonry is carried 15 ft. above their bases, when they will be removed and some of them will be placed on wooden trestle-work, built on the lower inclined face of the dam.

It is expected that the whole dam will be completed to the full flow line by May, 1905.

*A detailed account of the changes, including a brief description of the dam as a whole and the reasons advanced as a basis for the changes, was printed in Engineering News of June 16, 1904, in the form of a paper presented to the American Water-Works Association by Mr. William R. Hill, M. Am. Soc. C. E., the former chief engineer of the Croton Aqueduct Commission. The report of the board of experts on the proposed changes was printed in Engineering News of Nov. 28, 1901, and was followed, during the next few months, by an extended discussion of the subject.

The changes which have been described are being carried out under the terms of the contract for the dam, made a dozen years or so ago. The contractors for the whole dam are Coleman, Breuchaud & Coleman, of New York City. Mr. J. Waldo Smith, M. Am. Soc. C. E., is Chief Engineer of the Croton Aqueduct Commission, and Mr. Charles S. Gowen, M. Am. Soc. C. E., is Division Engineer of the dam.

THE COMPLETION OF THE LONGITUDE GIRDLE OF THE GLOBE: DETERMINATION OF THE DIFFERENCE IN LONGITUDE BETWEEN SAN FRANCISCO AND MANILA.

By Edwin Smith.*

The recent determination of the difference of longitude between San Francisco and Manila by the use of the cables of the Commercial Pacific Cable Co., by the Coast and Geodetic Survey, completed the longitude girdle of the earth, and the results will be published in detail in the Report of the Superintendent of the Coast and Geodetic Survey for 1904. In anticipation of that report the results are now made public by authority of the Superintendent.

The parties in charge of the writer and Assistant Freemont Morse started for the field in March, 1903, and finally completed the field work in May, 1904. The distance by cable from San Francisco to Manila (7,847 nautical miles) is covered by four cables extending from San Francisco to Honolulu, Honolulu to Midway Island, Midway Island to Guam Island and Guam Island to Manila.

In the determination of time at the several stations the method set forth in Appendix 7 of the C. & G. Survey Report for 1898 was carried out, except that it was impossible to observe the same stars at both stations involved in each determination of a difference of longitude on account of the great difference of longitude and also the unfavorable weather conditions, which often necessitated the observation of different stars on consecutive nights. The stars were selected almost exclusively from the list given in the Berlin "Jahrbuch," and it is believed that the results must be very little if any in error on account of errors of the right ascensions.

The greatest difficulty to be overcome was the elimination of the difference of personal equation of the observers. Since 1891, the Germans have used the Repsold Registering Micrometer on their transits, and their experienced observers seem to have almost no personal equation in its use for the determination of time. In eight differences of longitude determined by them, 1893 to 1903, an exchange of instruments and observers took place midway in the work of each determination thus giving a determination of the sum of the difference of instrumental and personal equations. The following results are taken from the Astronomisch-Geodätische Arbeiten of the Preussischen Goedätischen Institutes for 1902 and 1904:

1893:	Ubagsberg-Göttingen	III	Borrass	II	Albrecht	— 0.009 s.
	Ubagsberg Bonn		"		"	— 0.019
	Bonn-Göttingen		"		"	— 0.034
1898:	Knivsberg-Kopenhagen	III	Albrecht	II	Schumann	— 0.034
	Knivsberg-Kiel		"		"	— 0.033
1900:	Potsdam-Bukarest	III	Albrecht	II	Borrass	— 0.017
1901:	Potsdam-Pulkowa		"		"	— 0.025
1903:	Potsdam-Greenwich	III	Albrecht	II	Wanach	— 0.000

Had no exchange of place of instruments and observers been made, the errors in the differences of longitude due to personal equation would in no case have been greater than 0.034. The addition of registering micrometers to the transits of the Coast and Geodetic Survey was considered, but this was found quite impossible in time for the Trans-Pacific work. An exchange of observers took place between San Francisco and Honolulu and difference of personal equation was determined by special observations as often as the observers met. The results are here given. The plus sign means that S observes later than M.

From the exchange of observers between San Francisco and Honolulu, April 20-29 and June 2-13, 1903 S — M = +0 .062 s. ± 0.008 s.

*Assistant, Coast and Geodetic Survey, Washington, D. C.

The following are the results from the ten special nights observation:

San Francisco	March 28, 1903	20 Stars.	S-M. =	+ 0.085 s.	± 0.017 s. weight 0.7
" "	April 1, 1903	20 "		+ 0.092	± 0.017 " 0.7
Honolulu	May 11, 1903	20 "		+ 0.109	± 0.010 " 1.0
"	June 27, 1903	20 "		+ 0.106	± 0.012 " 0.8
"	April 18, 1904	20 "		+ 0.080	± 0.009 " 1.1
"	April 21, 1904	17 "		+ 0.079	± 0.007 " 1.4
San Francisco	May 6, 1904	22 "		+ 0.075	± 0.013 " 0.8
" "	May 7, 1904	26 "		+ 0.045	± 0.012 " 1.0
" "	May 8, 1904	22 "		+ 0.043	± 0.015 " 0.8
" "	May 9, 1904	26 "		+ 0.087	± 0.015 " 0.8

The mean of the ten nights is:

$$S - M = + 0.077 \text{ sec.} \pm 0.005 \text{ sec.}$$

This result with an assigned weight of 2.0 combined with that determined from the exchange of observers between San Francisco and Honolulu with an assigned weight of 1.3 gives

$$S - M = + 0.071 \text{ sec.} \pm 0.007 \text{ sec.}$$

This personal equation is applied to the differences of longitude between Honolulu-Midway, Midway-Guam, Guam-Manila. The difference of longitude between San Francisco and Honolulu is corrected by the personal equation determined from the exchange of observers only. The range of these results is no greater than should be expected from the computed probable errors and may therefore be due to errors of observation rather than to variation of personal equation. The observers were so placed that personal equation is eliminated in the final longitude of Guam and enters only once in the final longitude of Midway and Manila. It does not seem that these longitudes can be seriously in error on account of personal equation.

The instrumental outfits of the five stations of the Commercial Pacific Cable Co., are similar. The Muirhead siphon recorders are exclusively used and a description of them can be found in "Submarine Telegraphs" by Charles Bright. The record is made upon a slip of paper by a siphon pen attached by two fibers to the coil of the recorder. The slip of paper is made to move by an electric motor at the rate of about two centimeters per second. In order that the paper and pen may be adjusted to the proper relation, the rollers over which the paper passes are attached to a stand capable of one vertical and two horizontal adjustments. It was necessary that all cable signals should be recorded on this slip of paper at the cable office. The problem was to refer the record of a signal received over the cable to the time as recorded by a break-circuit chronometer. It was solved in the following manner.

To the armature of a 20-ohm Morse relay was attached an arm of aluminum, which carried a siphon pen exactly like the one on the cable receiver. This relay was mounted on a stand capable of a vertical and two horizontal adjustments. This was called the chronometer cable recorder. It could be placed on the table in front of the cable receiver and so adjusted that its syphon pen would record on the slip of paper parallel to the record made by the pen of the cable recorder. The chronometer and battery being put in circuit with the chronometer cable recorder a record of the chronometer seconds was made on the slip and any signal coming over the cable was recorded by the pen of the cable recorder also on the slip. This cable signal could be brought vertically down to the record of the chronometer, and its time read off by the usual scale. On account of the impracticability of always adjusting the pens exactly opposite each other the cable signal has a correction the determination of which will presently be explained. Signals were sent by a key such as is used in correspondence over the cable. It is a double key by which a positive or negative current can be sent to the cable. An attachment was made to these keys at the C. & G. Survey office, by which the circuit through the chronometer recorder would be broken the instant the current was put on the cable and thus record the chronometer time of the signal sent. When sending signals the local cable receiver is generally disconnected, but by so arranging a shunt that a small portion of the sending current would pass through the coil of the local receiver a sharp record was also made by the pen of the cable receiver and thus the relation of the two pens was obtained.

At the stations San Francisco, Honolulu and Manila the observatories were so far from the cable office that the chronometer cable recorder at the cable office could not be placed in circuit with the chronometer at the observatory. Another chronometer was therefore placed at the cable office to be used in the exchange of the cable signals. At these stations the cable offices and observatories were connected by land lines by which the two chronometers were compared before and after the exchange of cable signals. At Midway and Guam the cable offices and observatories were only a few hundred feet apart so that the chronometer cable recorder at the cable office could be placed directly in circuit with the chronometer at the observatory, and no comparisons of local chronometers was necessary. The results indicate that time signals over long cables can now be exchanged with as great accuracy as over the best land lines.

By the transmission time of a signal over a cable is meant the time that elapses between the instant the record is made on the slip at the sending station to the instant the record is made on the slip at the receiving station. These times as determined from sending signals in both directions over the four cables are given in the last column of the following table. The other data in the table have been kindly furnished by Mr. G. G. Ward, Vice-President and General Manager of the cable company.

	Diameter of Copper Conductor, Inch.	Length of Cable in Nautical Miles.	Resistance of Copper, Ohms.	Electromotive Force Used, Volts.	Transmission Time, s.
San Francisco-Honolulu	0.1801	2 276.3	5 054	50	0.189
Honolulu-Midway	0.1122	1,339.0	6,530	30	0.118
Midway-Guam	0.1809	2,606.9	4 758	50	0.185
Guam-Manila	0.1183	1,631.6	7,235	35	0.156

The following are the differences of longitude corrected for personal equation, as determined over these four cables:

	h.	m.	s.	s.
San Francisco-Honolulu	2	21	38.919	± 0.008
Honolulu-Midway	1	18	03.219	± 0.015
Midway Guam	2	31	53.584	± 0.010
Guam-Manila	1	34	43.263	± 0.010

The San Francisco station is 8 h. 09 m. 48.813 s. ± 0.056 s. west of Greenwich. (See "The Longitude Net of the United States and its connection with that of Europe, 1866-1896," Appendix 2, "Coast and Geodetic Survey Report, 1897," and also "The Transcontinental Triangulation," pp. 820 and 826 "Coast and Geodetic Survey Special Publication, 1900.") The Manila station is 0.224 s. west of the Dome of the Manila Cathedral, which is the accepted point of reference in Manila. Combining these with the above differences of longitude we have the following longitudes:

	h.	m.	s.	s.
Honolulu Transit West of Greenwich	10	21	27.752	± 0.056
Midway Transit West of Greenwich	11	49	30.951	± 0.057
Guam Transit East of Greenwich	9	38	35.465	± 0.058
Manila Cathedral Dome East of Greenwich	8	03	52.426	± 0.059

COMPARISONS WITH FORMER DETERMINATIONS OF THE LONGITUDES OF THE SEVERAL STATIONS.

HONOLULU.—In a former issue of Engineering News* an elaborate discussion of former determinations of the longitude of Honolulu was

*Nov. 5, 1903.

given by Mr. John F. Hayford, of the C. & G. Survey, to which the reader may refer. We will give here only the most reliable one. In 1874 Capt. G. L. Tupman, Royal Marine Artillery, in charge of the British Transit of Venus expedition of that year determined the longitude of this station by seven results from occultations of stars by the moon, 52 results from observations of moon culminations and 60 results from the observations of zenith distances of the moon combined with the observed culminations and zenith distances of well known stars. His result officially communicated to the Hawaiian Government is:

10 h. 31 m. 27.2 s.

The longitude determined by the C. & G. Survey by the cables referred to the same point is:

10 h. 31 m. 27.236 s.

A remarkably close agreement.

MIDWAY ISLAND.—These islands were discovered by Capt. N. C. Brooks in the "Gambia," July 5, 1859. In 1867 Capt. Reynolds, U. S. N., in the "Lackawanna," visited the islands and gave the longitude of the North point of the larger island as

Longitude 177° 18' 20" West.
11 h. 49 m. 13.3 s.

In 1900 a survey was made of the islands by the officers of the U. S. S. "Iroquois," under the command of Lieut-Commander C. F. Pond. The Hydrographic Office Chart No. 1951 is based upon this survey and the longitude given for the point marked Observation Spot is:

Longitude 177° 21' 30" West.
11 h. 49 m. 26 s. West.

The longitude determined by the C. & G. Survey by the cables referred to the same point is:

Longitude 177° 22' 46.4" West.
11 h. 49 m. 31.091 s. West.

GUAM ISLAND.—In 1891 M. de Freycinet, in the French corvettes "L'Uranie" and "La Physicienne," made a survey of the southern part of the Mariana or Ladrone Islands and gave the longitude of Fort Santa Cruz in the Harbor of San Luis D'Apra, Guam Island as:

144° 39' 45" East.*
9 h. 38 m. 39 s. East.

In 1875 the island was visited by Capt. Knorr of the German Navy, in the ship "Hertha." The longitude of Fort Santa Cruz was determined to be:

144° 39' 30" East.†
9 h. 38 m. 38 s. East.

In 1899 the officers of the U. S. S. "Yosemite" made a survey of the Harbor of San Luis D'Apra. They built a concrete pier on Fort Santa Cruz and determined its longitude by transit observations and the transportation of chronometers back and forth from Yokosuka, Japan. The longitude of this pier as communicated by the Hydrographic Office is:

Longitude 144° 39' 21.45" East.
9 h. 38 m. 37.43 s. East.

The longitude determined by the Coast and Geodetic Survey by the cables referred to the same point is:

Longitude 144° 39' 42.15" East.
9 h. 38 m. 38.81 s. East.

MANILA.—Two former telegraphic determinations of the longitude of Manila can be deduced, one via Madras, India, and the other via Vladivostok, Siberia. The longitude of Madras has been determined by five independent series of observations, and a resume of them has been given by Capt. Burrard, in Appendix No. 2, Vol. XVII. of "The Great Trigonometrical Survey of India." They are as follows:

	h.	m.	s.	s.	
Series A....	5	20	59.750	± 0.155	1874-5 and 1881-2
B....	5	20	59.910	± 0.163	1874
C....	5	20	59.137	± 0.022	1876, 1881, 1892-4-5
D....	5	20	59.223	± 0.127	1874-7
E....	5	20	59.421	± 0.123	1874-7

Series A. is via Pulkowa, Moscow, and through Siberia to Vladivostok by the Russians, and thence to Madras by the U. S. Navy. As the series will be used for the deduction of the longitude of Manila direct it will not be considered in the determination of the longitude of Madras.

*See Findley's North Pacific Directory, page 800.
†See Annalen Hydrographie, 1875, page 284, and also Geographical Positions, compiled by Lieut. Commander Green and published by the Hydrographic Office, U. S. N., 1883.

Series B. D. and E. were mostly determined by the parties who went out to observe the Transit of Venus in 1874, and it is stated that the observations were not conducted with the refinement necessary for the determination of fundamental longitudes. It therefore seems at the present, that series C. must be considered the only reliable determination of the longitude of Madras. It is made up of ten differences of longitude in which personal equation was eliminated by the exchange of observers or by special observations. The observers were also so placed that in the final longitude of Madras personal equation would be eliminated. One link in this series is the difference of longitude between Potsdam and Greenwich, and this was redetermined in 1903 by the Germans in most refined manner and the result increases the longitude of series C. by 0.098 s. This increased result will be used in the deduction of the longitude of Manila.

The difference of longitude between Pulkowa-Greenwich was redetermined by two steps, Pulkowa-Potsdam and Potsdam-Greenwich by the Germans in 1902-3. This work supersedes the older determinations and will be here used. The difference of longitude Vladivostok-Pulkowa is made up of thirteen differences of longitude by the Russians. In all the work between Vladivostok and Greenwich personal equation was eliminated as in the case of Madras. In 1881-2 the differences of longitude of Vladivostok-Manila and Manila-Madras was determined by officers of the U. S. Navy. The entire work consists of ten differences of longitude. Seven of them are involved in the difference of longitude Vladivostok-Manila and four in the difference of longitude Manila-Madras. In this work the differences of longitude are not corrected for personal equation, and no information as to the values of personal equation of the observers that can now be used can be found. The endeavor was made to so place the observers that personal equation would be eliminated as far as possible in the resulting longitudes. The difference of longitude Vladivostok-Manila remains uncorrected for plus the difference of personal equation of two of the observers and the difference of longitude Manila-Madras remains uncorrected for plus twice the difference of personal equation of the same two observers. The two results for the longitude of Manila are as follows:

		h.	m.	s.	s.	
1.	Manila Cathedral Dome-Madras, U. S. Navy	2	42	53.000	± 0.057	+ 2 (N-G)
	Madras-Greenwich, English and Germans	5	20	59.238	± 0.022	
	Manila Cathedral Dome-Greenwich	8	03	52.238	± 0.061	+ 2 (N-G
2.	Vladivostok-Manila Cathedral Dome, U. S. Navy	0	43	38.500	± 0.059	+ (N-G)
	Vladivostok-Greenwich, Russians and Germans,	8	47	31.197	± 0.146	
	Manila Cathedral Dome-Greenwich	8	03	52.697	± 0.157	± (N-G)

The symbol (N.-G.) indicates the unknown personal equation correction to these determinations of the longitude of Manila. Owing to this unknown correction it is difficult to give proper weights to these two values of the longitude of Manila to combine them with the value recently determined by the Coast and Geodetic Survey via United States. It is probable that the value of (N-G.) is plus and the corrections if known would bring the two longitudes of Manila closer together. Taking the mean of the two values we have:

Manila Cathedral Dome—Greenwich,
8 h. 03 m. 52.468 s. + ½ (N-G)

which differs only 0.042 s. or 61.7 feet from the C. & G. Survey result.

In 1881-2 the U. S. Navy adopted for the longitude of Madras

5 h. 20 m. 52.42 s.,

which gave for their value of the longitude of Manila

8 h. .03 m. 52.42 s.

This value which differs only 0.006 s. or 8.8 feet from the C. & G. Survey result has been used since 1882.

The difference of longitude San Francisco-Manila, determined by the C. & G. Survey, has a probable error of 0.022. The longitude of San Francisco depends upon the longitude net of the United States and its connection with that of Europe, and includes 72 differences of longitude between 45 points. Four of these differences of longitude are Trans-Atlantic, three by the Coast and Geodetic Survey and one (1892, not yet published) by the English and Canadians. In view of these facts and the unknown correction for personal equation in the other two values of the longitude of Manila, the value determined by the Coast and Geodetic Survey will be accepted.

SEWAGE TREATMENT IN GREAT BRITAIN AND SOME COMPARISONS WITH PRACTICE IN THE UNITED STATES.*

There is a greater dissimilarity in the conditions affecting the treatment of sewage in Great Britain and the United States than is generally supposed. This dissimilarity includes differences in soil, climate, the personal habits of the people, municipal customs and professional standards. The soil, as a rule, is clayey and damp, requiring drainage to fit it for ordinary farming purposes. Sand and gravel suitable for filtering materials are scarce, thus necessitating recourse to cinders, clinkers and coke. The climate is more humid and less sunny than ours, although the total yearly rainfall in many sections is what we should call low. Personal habits and local usage in Great Britain favor economy in the use of water, thus tending to a very strong sewage, but the strength of the sewage in many municipalities is greatly reduced by the number of pails, dry earth closets and even old-fashioned privies and middens, which have not yet given way to water closets. On the other hand, combined sewerage systems are the rule in Great Britain, whereas in the United States separate systems are far more common, and few American municipalities with combined systems have yet built works for the treatment of sewage.

Professional standards in England, in so far as they relate to the sewage problem, are unlike those in the United States. Engineers, chemists and bacteriologists there more commonly take out patents on sewage purification or other sanitary works than do the same classes of men in the United States.

The density of population in many parts of Great Britain and the small size of the largest streams, when compared with our great rivers, and the existence of conservancy boards to prevent or lessen the pollution of streams in England have combined to force sewage purification upon that country much more rapidly than upon this. As a consequence, sewage works literally crowd upon each other in some parts of England. Even if the soil was favorable to the treatment of sewage it would be difficult, in more than one section, to find sufficient land at a reasonable price for sewage farming, and not easy to find enough for intermittent filtration. But the soil is rarely what one would choose, if a choice presented itself, for either broad irrigation or intermittent filtration. Moreover, the difficulties are increased by the fact that most of the sewers are on the combined system, and the further fact that the Local Government Board insists, as a rule, on the treatment of a considerable portion of the storm flow.

Sewage is far more commonly pumped in Great Britain than in the United States. This increases the cost of disposal and leaves less money available for treating the sewage, but it gives greater freedom in the choice of methods of disposal than is possible where the location and arrangement of works is largely governed by the gravity head available for delivering the sewage where wanted for treatment.

The combination of the various factors cited has acted as a powerful stimulus to the search for new methods of sewage treatment in Great Britain, and the possible rewards for notable success doubtless account in part for the strong tendency toward proprietary processes.

Both fortunately and unfortunately for England, it has a Local Government Board which

*Being the Introduction to "British Sewage Works" (just published), by M. N. Baker, Associate Editor of Engineering News.

through its veto power over permanent municipal loans not authorized by Parliament, controls to a very large extent the character of all sewage disposal works.* The existence of this board has been fortunate in that the board, amidst all the activity over new and diverse methods of sewage treatment, has, with a calmness and conservatism that have been almost maddening to those directly interested, passed judgment on each scheme and, when approving any new project, has insisted on what it considered to be adequate safeguards. The control of the Local Government Board over sewage works has been unfortunate because the board has been so largely a negative and so wholly a conservative force.

The nearest parallel we have to the British Local Government Board is the Massachusetts State Board of Health, but the latter body has been given both the legal power and the financial means to enable it to couple its power of veto and its virtual power of amendment of plans for sewage works with suggestions based on exhaustive experimental studies and practical observations. The Massachusetts State Board of Health, therefore, has been able to guide the municipalities under its jurisdiction, while the Local Government Board can do, or at least has done, comparatively little except to hold the municipalities of England and Wales to more or less arbitrary standards.

While the Massachusetts experiments have been conducted primarily for the people of that State, their results have been studied and to a large extent followed by engineers and sanitarians throughout the United States. The leadership of Massachusetts would alone largely account for the fact that sewage disposal in America shows less diversity of method than is the case in Great Britain.

No one should be misled by the foregoing paragraphs into thinking that sewage treatment in the United States has become either settled or uniform. Far from it. There are evidences in many sections that the diversity so prevalent in British theory and practice has made itself felt here. American engineers who have had an opportunity to see for themselves what is being done in Great Britain have, for the most part, either continued to recommend the methods found acceptable in our own practice or else have advised experimental plants or one or two trial units before adopting a whole scheme based on British ideas.

Unfortunately, every American engineer cannot go abroad for the purpose of studying sewage disposal works, and naturally the few who can and do go do not feel called upon to make public the whole result of their investigations. British engineers and chemists have written numerous books and papers on sewage disposal, but of late these have dealt more with the theoretical and experimental work than with plants in every-day use. It therefore became true that for many years, in neither Great Britain nor America, was there any comprehensive description of the representative British sewage disposal works of the day.

In the early history of American works for the treatment of sewage, Engineering News commissioned the writer to prepare a series of articles on "Sewage Purification in America." Those articles were collected and reprinted in 1893, and comprised descriptions of nearly if not quite all the municipal plants for the treatment of sewage then existing in the United States. A large percentage of the descriptions were based on visits by the author to the works described.†

Some ten years having elapsed, during which many new, or at least modifications of old, methods of sewage treatment had come to the front, particularly in Great Britain, the writer seized an opportunity, generously afforded by the Engineering News, to visit a large number of representative British sewage works and to meet many of the leading British experts in sewage disposal. The result is the present book, which, it may be added, is primarily descriptive of the works visited.

*To secure Parliamentary sanction for a loan is likely to be a long and expensive process.

†Subsequently the author of the present book joined with Mr. George W. Rafter, M. Am. Soc. C. E., in the production of "Sewage Disposal in the United States," which was the first comprehensive American treatise on the theory and practice of sewage disposal.

Twenty-four British sewage works were visited by the writer between March 20 and June 20, 1904. It is believed that these works are fairly representative of British sewage disposal practice of to-day. They include examples of both old and new methods of treatment and also of both large and small works.

Aside from five sewage farms and three chemical precipitation plants, the works combine two or more methods of treatment and are not easily classified. The readiest and perhaps the most reasonable basis of classification for the 16 combined works appears to be the final method of treatment employed. Using this classification, we have eleven works with contact beds,* and five with percolating filters, besides the five sewage farms and three chemical precipitation plants already mentioned.

The preliminary treatment at the 16 combined works consists principally of septic tanks, for part or all of the sewage. Some of the works make use of sedimentation for all and others for a portion of the sewage treated, and still others employ chemical precipitation in like manner. The majority of the septic tanks are open.

The paragraphs immediately preceding summarize briefly the main features of the works visited. A broader view of the whole subject suggests the following conclusions and comments on sewage treatment in Great Britain:

Chemical precipitation is rapidly giving way to plain sedimentation and to septic tanks, more generally the latter, but many precipitation works are still in operation, and even now Glasgow is steadily proceeding with the construction of a series of such works. The conditions at Glasgow, however, are exceptional. It should be remembered that few figures have yet been published which enable one to make an accurate comparison of the relative costs of chemical precipitation and of effecting the same results by the newer methods of treatment. Most of the comparisons thus far made include operating expenses only. More figures relating to capital charges are needed.

Sewage farming has by no means come to an end, although in many instances it is being abandoned as rapidly as local circumstances will permit. Not a little of the apparent failure of sewage farming has been due to the faulty methods employed as preliminary to the application of sewage to the land. Where the land available for sewage farming is defective in quality or deficient in quantity, it has been necessary to resort to a preliminary process of sedimentation, chemical precipitation, or some method of filtration, and this necessity has furnished the opportunity for exploiting the conceits of visionaries and of the proprietors of a multitude of patented processes of sewage treatment. Most of these processes have proved either futile or ruinously expensive, but too often the condemnation for their failure has been heaped on sewage farming instead of on the preliminary treatment.

It should be explained for the benefit of those unfamiliar with the history of sewage treatment in England and Wales that for years past the Local Government Board, which controls most municipal improvements involving loans, has insisted on the final application of sewage to land, regardless of the previous method employed to treat the sewage.† This has virtually made sewage farming a necessity, wherever any departure from discharging crude sewage into a stream or the sea has been adopted. Acting under compulsion, it is not strange that municipalities and their engineers and farm managers should often lay out and operate sewage farms in a makeshift fashion. While sewage farming in Great Britain has suffered unjustly at the hands of both its friends and its enemies, there is little in the conditions prevailing in that country to indicate that it would be a success in the United States, except in those sections where every drop of available water is needed for ordinary irrigation.

Intermittent filtration plays so subsidiary a part in Great Britain, and is so different there from what it is here, that we have little regarding it to learn from British practice. Nor does there seem to be much reason, based on British experience, why we should hasten to change from intermittent filtration to more rapid bacterial processes. It would seem to be worth while, in the case of new works, to make estimates of the cost of intermittent filtration as compared with contact and percolating filters.

Septic tanks have not eliminated the sludge problem, as was claimed for them at the outset, nor has it yet been fully determined what percentage of sludge they will eliminate nor what can best be done, in the case of very large works, with such sludge as is produced. In the case of municipal plants, at least, it appears that most of the tanks thus far built are open, and many British engineers and chemists believe that open tanks are as efficient, and, as a rule, in other ways as satisfactory as closed tanks. In cold climates the closed tank may be advantageous on account of conserving heat and, in proximity to dwellings and highways, covers may also be desirable to prevent possible annoyance to people in the vicinity.

Contact beds have certainly made more headway than percolating filters as final means of treatment in Great Britain, but at present the percolating filters seem to be forging toward the front. Here again we lack figures for capital charges and operating expenses under the two systems. It seems to be pretty well agreed that contact beds alone are insufficient, even with double contact, and that double or triple contact is required where a high degree of chemical purification is required. Automatic apparatus for filling and emptying the beds is common but by no means universal either in practice or in the opinion of engineers and chemists. The best material for contact beds does not seem to have been settled, but the most common is cinders or clinkers, the clinker from refuse destructors having the preference. Most of the British contact beds have water-tight bottoms and sides, the necessity for which is not always apparent.

Percolating filters are a later development than contact beds, and, as previously stated, appear to be growing in favor. One of the chief questions still at issue is the best form of sprinkler or distributor, and another is the relative advisability of removing suspended matter from sewage before and after it has passed the filters.

In general, attention may again be called to the lack of comparative data for judging the relative merits and costs of different methods of treatment, as determined by the results obtained through a series of years in works operated on a practical, every-day basis. Attention may also be called to the very heavy capital charges which have been and are being incurred at many British sewage works, which must go far toward offsetting any advantages gained by rapid rates of treatment. Finally, it seems strange to an American to see so much perishable material used for filter beds, and one cannot but wonder whether this is wholly due to lack of permanent material at reasonable prices or to some fancied virtue in the material itself. Present indications are that in the United States we shall do better to continue to use sand for our finer material, and, if coarser material is required, to employ gravel or broken stone, rather than cinders, clinker and broken brick.

*For the convenience of any readers not familiar with the processes of sewage treatment now in use, definitions or brief descriptions of the same have been prepared and may be found in an appendix to this book.

†Recently this requirement has been modified in certain instances.

A NOVEL METHOD OF PLUMBING A CHIMNEY DURING CONSTRUCTION.

By F. M. Goodhue.

Engineers may possibly be interested in an account of a somewhat novel expedient used by the writer in plumbing a large chimney during construction, which was erected in the summer of 1902, at Lawrence, Mass. The chimney itself was of the ordinary construction, 179 ft. high above the foundation, 18 ft. in diameter at the base, with an 8 ft. flue, and was erected for the new power plant of the Champion-International Paper Co. Dean & Main, of Boston, were the designers, and Geo. N. Cole, of Lawrence, the contractor. The method of plumbing was suggested to the writer by R. A. Hale, engineer of the Essex Co.,

as being practical and doing away with all lines, wires and fixed contrivances.

After the chimney was started, a transit point was established at some distance from the base of the chimney, and a line run over the center point; in this line, near the base of the chimney, a stake was driven, the line being marked by a tack therein. Later this mark was replaced by one on a card fixed to the chimney itself. Another transit line nearly at right angles with the former was also established. As the chimney was built up, any deviation whatever from the perpendicular in any direction would be at once noted from either one or both of the two lines, and steps taken to correct it. This was rendered easier by the fact that a center pole was established on the workmen's staging (interior), around which swung a radial arm, upon which was marked the offset of each course of bricks, thus maintaining the exact circular shape of the chimney, and the pole, about 3 ins. in diameter, was used for the sight from the transit. The procedure without the pole would be upon the same principle, an assistant erecting a plumb at the exact centre of the chimney as then building. In this way the chimney was carried up, with no delay or bother to the workmen from ordinary plumbing.

To satisfy curiosity and check results, after the chimney was finished a heavy weight was swung in the center, and it was found by this means that the deviation was about ⅜ in.

It is evident the method lends itself to other construction, as, for instance, where masons carry up an important corner and some other check besides their ordinary spirit levels is required.

A LARGE TURBINE-DRIVEN CENTRIFUGAL PUMP.

A few months ago, in our issue of June 2, 1904, we presented the results of tests made by Professors J. E. Denton and W. Kent on several high-speed centrifugal pumps of the De Laval Steam Turbine Co., of Trenton, N. J. A very large pump of the same type has recently been built by that company, and since centrifugal pumps at present claim much interest, we show an outline drawing and two photographs of this machine in the accompanying cuts, Figs. 1 to 3.

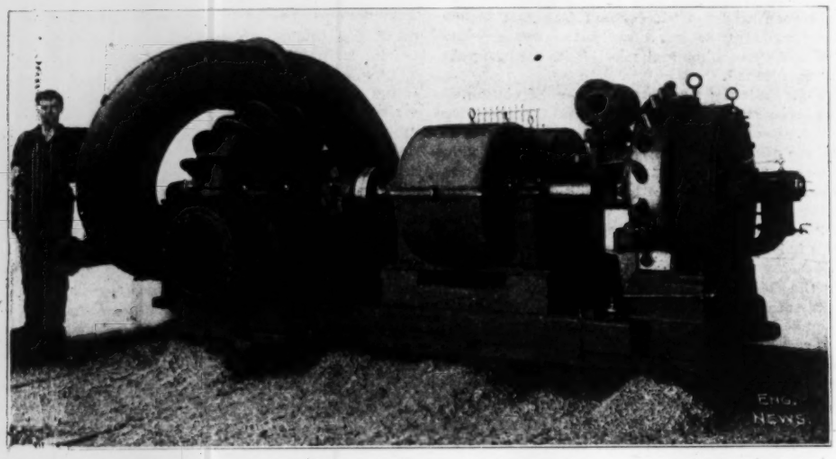


FIG. 1. 300-HP. TWO-STAGE CENTRIFUGAL PUMP UNIT, CAPACITY 10,000,000 GALLONS AGAINST 125-FT. HEAD. BUILT BY THE DE LAVAL STEAM TURBINE CO., TRENTON, N. J., FOR THE SOLVAY PROCESS CO., SYRACUSE, N. Y.

The pump was built to the order of the Solvay Process Co., of Syracuse, N. Y. It is a two-stage pump and is direct-connected to a 300-HP. De Laval steam turbine of standard construction. The combined unit is required to deliver 10,000,000 gallons per 24 hours against a head of 150 ft., under the conditions of 125 lbs. steam pressure and 28 ins. vacuum. The speed of the pump shaft under these conditions is 900 r. p. m. Fig. 1 shows the completed machine.

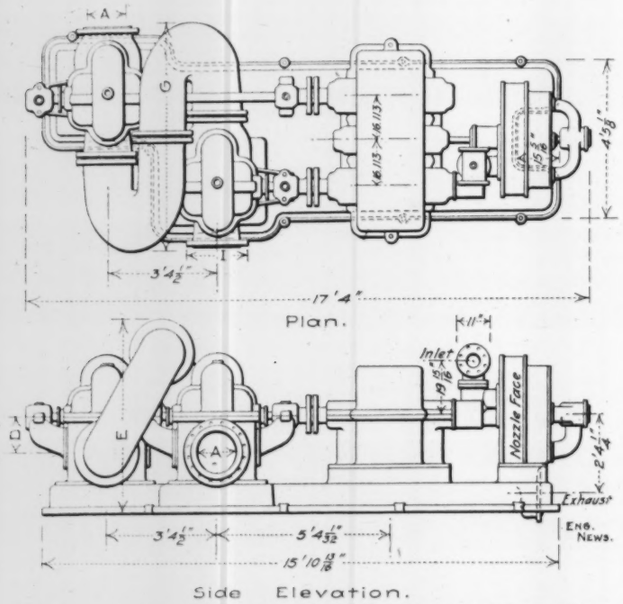


FIG. 2. PLAN AND ELEVATION OF 300-HP. CENTRIFUGAL PUMP.

The arrangement of the two elements of the pump with respect to the driving steam-turbine is clearly exhibited by Fig. 2, which gives a ground-plan and a side elevation of the machine. The turbine is at the extreme right; it has a turbine disk of 31⅜ ins. outside diameter, running at about 10,500 r. p. m. The turbine shaft carries a pinion lying between two spiral gears (herring-bone), mounted on the two pump shafts. These gears contained in the gear box to the left of the turbine, reduce the speed from 10,500 at the turbine shaft to 900 r. p. m. at the pump shafts. The two elements of the pump, each a complete pump in itself, are at the left of the bed. Because of their width they are staggered a short distance, and a double-curved connection pipe leads from the discharge of one pump element to the suction of the other.

The two elements are exactly similar. The single impeller-wheel of each is 22 7-16 ins. in diameter over all; it is of the "closed" type, as is shown in Fig. 3. The material of the wheel is phosphor-bronze. There are no stationary guide-vanes surrounding the wheel.

The pump-case is made in two parts, divided on the horizontal center plane, so that the machine can be inspected without removing or dismounting any shaft, bearing or pipe. The upper half of the case is strengthened by transverse ribbing, seen in Fig. 1. The pump-shaft bearings are bushed ring-oiling bearings outside of the case; the shaft has packings separate from the bearings. For cold water, as in the present case, the packing is made by cup leathers, which are set out by the pressure; graphite-flax is used for hot water. Brass sleeves surround the shaft at the packings. There is a drip-chamber between packing and bearing, which catches any leakage. The construction secures efficient packing and good lubrication, and keeps the bearing-pressure off the packing.

A PRELIMINARY REPORT ON AN ADDITIONAL water supply for New York has been made by Mr. George W. Birdsall, Acting Chief Engineer of the Department of Water Supply, Gas and Electricity. The plan proposed for immediate construction includes a large storage reservoir on Esopus Creek, west of the Hudson River, a 300,000,000-gallon aqueduct to the borough of the Bronx, a 14,000,000,000-gallon reservoir in the Bronx, large conduits from the Bronx reservoir to both Manhattan and Brooklyn boroughs, a reservoir on Long Island and distributing mains in four of the five boroughs, or in the whole city excepting Staten Island. The estimated cost of the work as outlined is about $90,000,000, including $7,000,000 for the distributing mains and nearly $12,000,000 for contingencies and engineer's fees. It is stated that the project has been approved by Mr. John T. Oakley, Commissioner of Water Supply, Gas and Electricity, but that it will be given a critical examination by Mayor McClellan before being referred to the Board of Estimate and Apportionment. The scheme cannot be carried out unless it receives the approval of the board just named.

A TRAIN BLOWN FROM THE TRACK is reported from the town of St. Francis, Kansas, under date of Sept. 28. A combination freight and passenger train going at a fair gait, about 25 mi. per hr., met a tornado, which blew most of the freight cars off the track, smashing them up badly. The single passenger car, containing some 35 persons, was lifted off the track and set down in the ditch alongside the roadbed "without even jarring the passengers and without even a window being cracked." The locomotive remained on the track.

Fig. 3. Phosphor-Bronze Impeller Wheel of 300-HP. Centrifugal Pump.

THE TRAVELING COAL HOISTING TOWER of the naval coaling station at the Charlestown Navy Yard, Boston, Mass. was wrecked by wind on Sept. 30. This is the second accident of this character to occur within a couple of months, the tower of the coaling station at East Lamoine, Me., being overthrown by wind on Aug. 20. (Eng. News, Sept. 1, 1904.) At Charlestown the tower traveled on a double line of tracks along the water side top of the coal pockets. During a heavy wind squall the anchor clutches gave way and the tower moved along the track until it reached the end and toppled over to the ground below. No one was injured, but the property damaged will amount to about $30,000.

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ADVERTISING RATES will be furnished upon application. "Want" and "For Sale" notices (special rates), see pages 26-27. The pages for new "Want" "Proposal" and "For Sale" advertisements are held open until Wednesday noon.

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Water parks or ornamental water basins formed by improving natural bodies of water are rare in the United States, but are comparatively common in Europe. The project of this kind now under way at and near Boston, Mass., known as the Charles River Dam and Basin, combined with the park and parkway development already carried out or planned, will provide one of the most notable water parks or basins in the world. Elsewhere in this issue the work now being planned for execution by the Charles River Basin Commission is described. Briefly, a dam across the Charles River between Boston and Cambridge will connect a portion of the Charles River which is now an eyesore at every low tide into a beautiful fresh water basin eight miles long, with a water surface of 830 acres. Of the 17½ miles of shore along this basin 16 is already either laid out in public parks or drives or has been acquired for that purpose. These parks and drives are connected with the Metropolitan Park System, of which the Charles River Basin will be a worthy center. Many another city or urban center in the United States might with ultimate profit to itself and its citizens develop water fronts which are now an eyesore into much-needed breathing places, at the same time improving local sanitary conditions, as will be the case at Boston, and adding greatly to the attractiveness and beauty of the city.

Not only does the length of haul affect the cost of all earthwork directly, but it often affects it indirectly by determining the character of the plant that can be used. This being granted, it follows that every earthwork contract of any considerable magnitude should set forth clearly the distance to which the earth must be moved from the different cuts. Yet nothing is more common in drainage specifications than to leave the whole matter of the earth disposal open to decision after the award of the contract. Within the year we have been asked several times by letter to outline the common practice in the disposal of earth taken from drainage ditches and canals. There is no common practice, and this being so, it is all the more desirable that drainage specifications be made clear and complete. The following serves as a good example of that kind of ambiguity that almost invariably results either in limited competition among bidders or high prices for insurance against an unfavorable interpretation of the clause.

> The object of the work being to drain the adjacent land, all material excavated shall be removed from the lines of the drain, either by hauling away or by spreading suitable material over the adjoining land of consenting property owners. All material wasted or spread as last above mentioned shall be sufficiently far from the lines of the excavation, and it shall be so graded that the material will not wash back into the drain, and that it will not impede the flow of water from adjoining land to the drain.

The contractor is left wholly in the dark as to three factors: (1) What proportion of the material will be "suitable" for spreading over adjoining lands; (2) what property owners will consent to the spreading; and (3) what distance from the drain the spreading must be carried. In a word, he must simply guess at the haul, which is equivalent to guessing at the method of excavation and transportation and the consequent cost of the proposed work.

Perhaps the most important lesson taught by this specification is that no engineer can draw specifications that will result in fair bidding prices, unless he makes the probable actual cost to the contractors a part of his study of the problem.

Some of our readers may recall the remarks in these columns some four years ago.* on two journals known as "The Southern Review of Commerce" and the "Southern Trade Record." The reading matter of each of these journals was made up of a collection of "trade write-ups" of the boldest kind, in each of which the reader was assured that as a result of most careful and unprejudiced investigation on the part of the editorial staff it had been determined that the goods of Blank & Co. were the best of their kind made. Prior to publication of these puffs, a proof of each was sent to the firm whose goods it advertised with a request that it be altered in any way desired and with an invitation to purchase a quantity of extra copies of the paper containing the article. It may be added that the "write-ups" were evidently penned with either the most superficial knowledge or no knowledge at all of the industry to which they referred.

In our issue of March 6, 1902, we again called attention to these journals and their methods and also to an imitator in the same field "The United States Trade Reports" of Cincinnati, edited by Geo. C. Carter. The two first-named journals seem to have disappeared from public notice, or at least we have heard nothing concerning their operations for a long time. "The U. S. Trade Reports," however, appears to be still doing business in the same old way. What this way is, is well-illustrated by the following correspondence:

To the Editor of Engineering News:

Sir: The enclosed communication explains itself. I trust you will give it the treatment it deserves.

For deliberate mendacity it is probably the worst of its pernicious kind. It announces to the public that, "as a result" of a decision "to make a thorough investigation" of garbage disposal plants, in accordance with "the invariable method pursued," which "consists in examining closely all the various makes by means of our editorial and reportorial staff," it is "prepared to state that there is no make of garbage disposal plants on the market to-day equal to those produced by the City-Wastes Disposal Company," etc.

The facts are these. As contractors or constructing engineers, we have not built a single garbage disposal plant. It is true we have designed such plants, but only as consulting engineers, privately employed by other engineers or contractors. In no instance has our connection with the designs been made public.

Such wilful misrepresentations, in a matter so vitally connected with municipal health and economy, should be an indictable offense. Yours truly,

City-Wastes Disposal Co.,
G. Everett Hill,
Vice-President City-Wastes Disposal Co.

156 Fifth Ave., New York City, Sept. 19, 1904.

The letter sent to the City-Wastes Disposal Co., follows:

Geo. C. Carter, Editor. Sheppee & Co., Pubs.
UNITED STATES TRADE REPORTS.
Editorial Department, 414 Home Street.
Cincinnati, O., Sept. 17, 1904.

City-Wastes Disposal Co., New York, N. Y.:

Gentlemen: The article we enclose you is an editorial prepared in answer to inquiries on the subject of Garbage Disposal Plants. As we have highly indorsed your plants, and as we desire to be as correct and comprehensive as possible, we ask that you add to or alter same as you may think best, and return as soon as possible. If you have any cuts that will illustrate the subject, kindly loan them to us and we will return them promptly.

As this is an editorial of course there is no charge for the publication, and if in addition you can use any extra copies of the issue in which it will appear, we will be pleased to make you the following special reduced rates, as we are desirous that you should get as much benefit out of it as possible:

The price of the United States Trade Reports is 15 cts. per copy, but we can supply you with 100 at 12 cts., 250 at 10 cts., 500 at 9 cts., or 1,000 or over at 8 cts. per copy, shipped to you. Or, if you will send us a list of names of those whom you wish to reach, we will mail marked copies to such, without any extra charge to you for the postage, wrapping, addressing or marking.

Although the publication does not depend on an order for copies, such an order will be appreciated by us.

Awaiting an early reply with corrected copy, we remain, with best wishes, Yours very truly,

United States Trade Reports,
Per Geo. C. Carter, Editor.

THE BEST MAKE OF GARBAGE DISPOSAL PLANTS.

We fully appreciate the difficulties the prospective buyer finds in obtaining a truthful and correct answer to the question, "Which is the best make of Garbage Disposal Plants?"

In the first place, he himself cannot know all the different kinds, and therefore cannot decide for himself.

Second, he cannot depend on the opinions of others, as they like himself cannot know all the various makes or may be prejudiced in favor of the kind they use.

Third, he cannot take his choice from reading matter and advertisements of manufacturers, since one and all believing they are right, and justified in saying so, claim their respective make the best.

Fourth, he cannot expect to have his question answered by any journal devoted to the trade, for in so doing such journals would commit financial suicide, since all other manufacturers, except the one given as the best, would at once withdraw their advertising patronage.

In view of the difficulties to a correct decision, this paper decided to make a thorough investigation, the result of which would be a decided answer as to which is the best. We fully realize the responsibility of making such a decision, since we are aware that our readers will accept it as final and worthy of fullest credence. For the benefit of new readers we wish to state that such faith on the part of our old readers is caused by their knowledge of the invariable method pursued by the Reports by which we can conscientiously give an independent and unbiased report on any article manufactured. This method consists in examining closely all the various makes by means of our editorial and reportorial staff, without the knowledge of any manufacturer interested, and further without making any charges, accepting any gifts or soliciting any advertisements from any one whose wares we may pass upon.

As a result we are prepared to state that there is no make of Garbage Disposal Plants on the market to-day equal to those produced by the City Wastes-Disposal Co., of 156 Fifth Ave., New York, N. Y. These plants are made of the best material, are durable in use and will give entire satisfaction at all times.

The company is thoroughly reliable in every respect and can be depended upon. Their business is conducted on a line that is pleasing to each and every customer, and promptitude is a special feature of their business methods. They also stand high commercially.

Our interested readers will do well in addressing them direct, as we are sure that all dealings with them will prove mutually beneficial and profitable.

It happens that we have on hand quite a collection of Mr. Carter's "editorials," and it is interesting to note the great similarity between this recent production and some that his creative brain produced a long time ago. For example, compare some of the paragraphs near the beginning of the above contribution to the literature of garbage disposal, with the following excerpt from a monograph of Mr. Carter's entitled "The Best Firebrick," proof of which he submitted to an unappreciative manufacturer on July 29, 1901:

A question of considerable importance to decide upon is, "Which is the best?" We appreciate fully the great difficulty that the prospective buyer finds in having his question answered in a correct and truthful way.

In the first place, he himself is not acquainted with the relative merits of the various makes, and therefore can not decide for himself.

Second, he cannot rely on the opinion of others, as they, like himself, may be unacquainted with the merits of other makes, or be prejudiced in favor of the one he uses, or have a selfish interest by means of a commission from a dealer or manufacturer, since one and all believe they are right and justified in saying so, and claim their respective makes as the best, all others are, of course, mistaken.

Third, he cannot expect to have his question answered by any trade journal, because in doing so such journals would commit financial suicide, since all other manufacturers except the one given the first place as "best" would withdraw their advertising patronage.

In view of such difficulties to a correct decision, this paper decided to make a thorough and exhaustive investigation, the result of which would be a definite and de-

*Dec. 14 and Dec. 28, 1899, and Nov. 8, 1900.

cided answer as to which was the very best make of fire brick.

If there is any such publication as the U. S. Trade Reports and if it has any readers, as a matter of common humanity toward them Mr. Carter should bring a little more variety into his editorial productions!

In conclusion, we may repeat our advice given at a former time that when any of our subscribers or advertisers receive such communications as that above quoted, they will do well to forward them to the Post Office Department at Washington, with the suggestion that concerns conducting such a business should be denied the use of the mails.

RECENT CHANGES IN LOCOMOTIVE DESIGN AS ILLUSTRATED BY THE EXHIBITS AT ST. LOUIS.

Elsewhere in this issue are described and illustrated the principal locomotive exhibits at St. Louis. While nearly everything there exhibited has already been described in technical literature and is not, therefore, strictly speaking, novel, the exhibit as a whole illustrates present advanced practice in locomotive design and makes clear some of the features in which notable changes have been made in the decade since the Columbian Exposition.

One of the most striking features is the great size of most of the engines. Excluding the smaller classes of engines, which are relatively fewer than at Chicago, most of the regular road engines are large and powerful machines. There is first of all the great Mallet duplex compound of the Baltimore & Ohio Ry., weighing 167 tons (all on the drivers) but this of course is a decidedly exceptional machine. Next in weight comes the double-end decapod engine of the Atchison, Topeka & Santa Fe Ry., 144 tons (with 117 tons on the drivers). Half of the engines weigh over 90 tons, and there are ten with over 80 tons on the drivers. In driving-axle loads, the maximum is 27½ tons in two of the Atlantic balanced-compounds, but here the effect on the track is reduced by the balancing feature. There are, however, two passenger engines with nearly 24 tons on each of the three driving axles, and two freight engines with 23½ and 24½ tons on each of the five and four driving axles. At the time of the Chicago exhibition the opinion was expressed that the heaviest locomotive there shown was too heavy to be a practical success. That locomotive was a decapod of 97 tons, with 86 tons on the ten drivers; there was also a twelve-wheel engine of 75 tons, with 66 tons on the eight drivers. The heaviest passenger engines weighed 60 tons, with 42 tons on four drivers. Within the past few years, however, there has been a general tendency to increased weight, and the record of being the "heaviest locomotive in the world" has been held and relinquished by engine after engine.

Another feature which has had a great development in the past decade is the very general use of small trailing wheels behind the rear drivers, to carry the load of the long and wide fireboxes. At the Chicago exhibition there were two four-driver and one six-driver passenger engines having such trailing wheels. Within recent years, however, this arrangement has become common for both passenger and freight engines of various types, and the old and long-familiar "eight-wheeler" (4-4-0) has been to a considerable extent replaced, for fast and heavy passenger service, by the Atlantic type having a pair of trailing wheels (4-4-2). The huge decapod freight engine of the Atchison, Topeka & Santa Fe Ry., also has the small trailing axle. In some of the engines, the trailing axle is carried by boxes in the main frames, but where the wheelbase is long, a special truck frame is used to give greater flexibility. In main frame construction, the American bar frame is still universally employed, but it is interesting to note that in some cases a plate frame is used to carry the trailing axle, on account of the plate being so much thinner than the bar, and thus allowing for greater width of firebox. On some of the engines the trailing axle has outside bearings, while on others the bearings are inside the wheels.

The number of compound engines seems to be rather small, especially among freight locomotives, and it is rather remarkable that the original Vauclain four-cylinder system (with superimposed cylinders), which has been applied to nearly 2,900 engines, is represented by only two engines, one of which is eleven years old. The balanced compound idea is represented by five engines, of separate and distinct designs; four of these are four-cylinder engines, while the fifth is a three-cylinder German engine built for specially high-speed service. There is also a four-cylinder duplex compound engine, but there is only one two-cylinder compound. There seems to be no doubt that the four-cylinder balanced-compound system which has been long and successfully employed in Europe, will be extensively adopted for high-speed work in this country.

The different types of compound locomotives represented may be classified as follows:

Four-cylinder balanced (2 American, 1 French, 1 German)	4
Four-cylinder tandem (American)	1
Four-cylinder superimposed (American)	2
Four-cylinder duplex (Mallet system, American)	1
Three-cylinder (German)	1
Two-cylinder (American)	1
Total	10

The use of the superheater on locomotives is a modern idea which has been largely discussed, and which has been put into practice to some extent in Europe, and has been recently experimented with in Canada. One of the large German engines in the exhibition is equipped with the Pielock superheater, consisting of a box surrounding the tubes in the boiler barrel; the steam passes from the dome to the superheater and thence returns to a box enclosing the throttle valve in the dome. In other systems the superheater is placed in the smokebox. It has been argued that under the conditions of practical service the economy in steam and fuel would not compensate for the extra expense, complication and weight. The results obtained abroad, however, seem to indicate that material advantages may result, and it is not improbable that American railways will find it advisable to follow the lead of European railways in this respect.

An examination of the three large foreign engines at St. Louis shows a rather remarkable proportioning of main and side rods as compared with those of American engines for similar service. The rods of the foreign engines are small and light by comparison, yet they are representative of standard practice, and in fact one of the engines belongs to a lot of 20 recently built for the fast and heavy passenger train service of the Prussian State Railways, while another is a duplicate of a number of engines built for the Paris & Orleans Ry. Evidently rods of these proportions do not give trouble in service, and it may be questioned whether the rods of American engines are necessarily so large and ponderous. On the other hand, breakages of rods are not unknown here. It is at least worth considering whether the greater stability of track of foreign railways and the consequent easier riding of the engines, does perhaps reduce the vibrations and strains to such an extent that the lighter rods may safely be used. It is true that in one of the foreign engines the side rods and high pressure main rod are of 5% nickel steel, but the proportions are very much the same in the other engines which have, we believe, rods of a high grade of ordinary steel. This feature of construction attracts very general notice, and certainly it would be worth while for designers and builders to look closely into this matter, with a view to a possible reduction of weight of reciprocating and rotating parts.

It may also be noted that the foreign engines show a finer finish, a closer attention to details and more regard for appearance than is usual with American engines. How far this is desirable or commendable must be largely a matter of opinion, but there is no doubt that the foreign engines are very handsome and attractive, and bear evidence of skillful workmanship as well as excellent design. The two large German engines are painted a dark green for the upper parts, while the wheels are red, and the frames brown, all highly finished and relieved with more or less brass work and lining or striping of different colors. The large French engine is painted black, rubbed down and finished to a surface resembling black enamel. The American engines (with the exception of a switch engine gaudy in red paint and nickel plated fittings) are uniformly black, relieved only by the lettering, and in a few cases by a minimum of gold striping.

Even the planished iron jacketing once used almost universally has now largely given place to a jacket of sheet iron painted black, which is cheaper and of equally good appearance. In this respect the engines certainly represent a practice which has become very general within the past few years.

In discussing the question of high-speed locomotives in our issue of June 16, we suggested the advantages of a head-end cab, and also suggested that if two enginemen are to be employed on the locomotives of fast trains (as has been advocated) one should be located in a cab at the front end to handle the engine, and the other in the rear or firing cab to attend to the boiler. This arrangement is practically that which is employed in the German high-speed engine, noted above, which has the engineman's cab in front of the smokebox and has also two firemen in the rear cab. An ingenious safety device is used, consisting of a throttle valve lever in the fireman's cab, so connected to the main throttle-valve lever in the front cab that the fireman can close the valve (independently of the engineman) but he cannot open it. A similar arrangement of cabs was applied to the Schneider 4-4-6 fast passenger engine at the Paris Exhibition of 1900 (Eng. News, Oct. 18, 1900). At that exhibition there was also an Italian locomotive with cab in front, but this was a "reversed" engine, running with firebox and driving-wheels in front, and the cylinders and smokebox at the rear. A large number of engines of this class have since been built for the Italian railway, but having the truck in front, under the cab.

Nearly half the engines exhibited, including both simple and compound locomotives, have piston valves; but all the foreign engines have slide valves, except that the German four-cylinder compound has piston valves for the high pressure cylinders. All the American engines have the Stephenson link valve gear, with the one exception of the Mallet duplex compound, which is practically of French design and has the Walschaert valve gear. The latter valve gear is used on the French engine and the two large German engines, although in Germany it is known as the Von Waldegg gear. The two small German engines have a rather curious arrangement of valve gear of the Allan straight-link type, in which the rods are worked from return cranks instead of eccentrics.

In the construction of the tenders the most notable feature is the use of the Vanderbilt type, with cylindrical tank, on three of the American engines. All the tenders (American and foreign) have four-wheel trucks, except that the tender for the narrow gage engine for Japan has a single leading axle and a rear truck.

LETTERS TO THE EDITOR.

Analyses Relating to Softening Iowa Well Waters.

Sir: A few words of explanation seem necessary in connection with Mr. L. M. Booth's communication, in your issue of Sept. 1, on "Analysis of Iowa Well Waters." He says: "To 'fish' around until the proper ratio of lime water to raw water is found may give results of approximate accuracy, yet it cannot be said to be either accurate or scientific." It soon developed in the process of the investigation that considerable excess of the lime water was necessary to be added to the raw water to remove the magnesium carbonate. The smallest amount required could be ascertained only by repeated trials. We contend that this is a proper and scientific method, and where the ratio is once established, the softening is easily, rapidly and scientifically effected. With the use of phenolphthalein, two or three minutes time would suffice to ascertain a subsequent variation in the quality of the water. Mr. Booth must well understand that much valuable scientific work has been done and results achieved by similar processes, let it be called *fishing around*, or designated by any other title. He also speaks of qualitative tests in a similar connection, whereas all the work was quantitative in its character.

Mr. Booth further criticises the conclusion that the raw water treated with the lime water *in excess* is quite unfit for drinking purposes, on account of the alkaline taste. The calcium oxide which it is stated in the original

paper (Eng. News, Aug. 18, 1904) was added in excess does not appear in the analysis because in the evaporation of the water to dryness, while exposed to the air, and heating the residue in an air bath several hours to constant weight, the thin film of calcium oxide spread out on the surface of the platinum dish was changed to the carbonate. This part of the work was simply to find the smallest amount of lime water that would remove the maximum of hardness, as a scientific fact, and not so much to discover the effect on potability which was incidental to the main thought. In the proportions used the taste of lime was not very pronounced. The addition of less lime water than we employed would not be tasted nor would it remove so much of the salts from solution. The writer would suggest this plan if the water is to be used as a beverage. The fact is that the raw water is generally used in this community with no ill effects so far as is known. Indeed, eminent medical authorities contend that hard water, even when it contains much more lime and magnesium than the well in question, instead of being injurious is positively beneficial.

After all has been said the fact remains, as stated in the editorial comment, that boiling under the normal atmospheric pressure does not remove from water all the so-called "temporary hardness," nor does the addition of lime water, although the latter removes a large precentage of the calcium and magnesium carbonates.

Nicholas Knight.

Mount Vernon, Ia. Sept. 19, 1904.

Wind Stresses in Knee-Braced Mill Buildings.

Sir: The action of knee-braces in resisting the wind forces on the sides and roofs of mill buildings, and their effect on the roof trusses and columns, is something of an open question among structural engineers, and is not usually given the attention it deserves in the design. Most writers either ignore the subject entirely or treat it in a superficial manner, while the few who have really attempted its solution obtain results so at variance with accepted practice as to render their results of no practical value.

Probably the demonstration most readily accessible to designers at the present time is that given by Mr. Hutchinson in "Modern Framed Structures."

I do not agree with Mr. Hutchinson in his demonstration in general, and for the sake of comparison have assumed the same dimensions of building as given on Plate 32, opposite p. 474 of "Modern Framed Structures," and the wind forces per Case V there given, that is, the wind acts on one entire side of building and roof and normal to the roof surface.

In the stress diagram the dead load and vertical component of wind on roof are laid off in the usual way and the windward and leeward reactions computed by moments; where these reactions divide the load line, the total horizontal wind on roof and one-half of wind on side of building are laid off as a horizontal line to the right. This force (23,700 lbs. in Fig. 3) is considered as being divided equally between the windward and leeward knee brace, the former being in tension and the latter in compression, and is resisted by the truss at the top of column, the kneebraces acting to prevent the distortion of the right-angle between column and truss.

The resisting forces appear in the stress diagram as increased vertical reactions and distributed stresses in the truss members as shown in the stress diagram, and are delivered to the foundations as vertical forces.

From the stress diagram (Fig. 3) we see that all members of the truss have their maximum stress on the windward side, except the member J^1K^1 in which there occurs a reversal of stress which we would expect from the compression in the leeward knee brace.

The accompanying table gives the stresses for the truss members in Fig. 1, those in the first column being from Fig. 3, and those in the second column from Mr. Hutchinson's diagram.

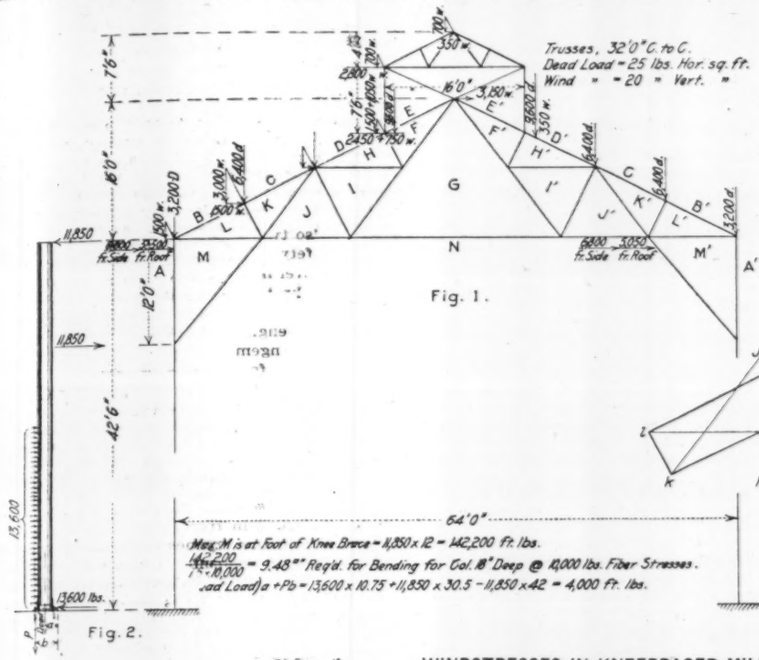
Trusses, 32'0" C. to C.
Dead Load = 25 lbs. Hor. sq. ft.
Wind " = 20 " Vert. "
64'0"
Max. M is at Foot of Knee Brace = 11,850 x 12 = 142,200 ft. lbs.
142,200 / 15,000 = 9.48" Req'd. for Bending for Col. 18" Deep @ 15,000 lbs. Fiber Stresses.
and Load) a +Pb = 13,600 x 10.75 + 11,850 x 30.5 - 11,850 x 42 = 4,000 Ft. lbs.
Fig. 1.

Fig. 2.

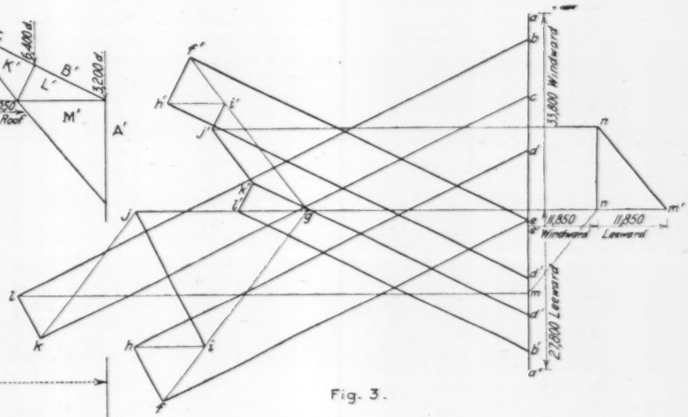

Fig. 3.

ENG. NEWS.

ILLUSTRATION.

Member.	Stresses Dunham.	Hutchinson.
B_1L_1	+97,200	+94,200
CK	+93,000	+91,200
DH	+75,200	+65,000
EF	+69,800	+69,600
FG	−41,400	−33,200
FH	+10,800	+13,600
GI	−29,200	−38,300
HI	−12,000	−15,000
IJ	+26,000	+34,300
JK	−27,400	−41,600
KL	+8,600	+9,500
LM	−87,000	−60,000
JN	−78,000	−51,200
GN	−49,400	−13,500
MN	−18,600	−32,300
B^1L^1	+55,000	−9,300
C^1K^1	+52,200	−12,300
D^1H^1	+68,400	+37,400
E^1F^1	+64,000	+32,000
F^1G^1	−33,200	−1,900
F^1H^1	+9,000	+11,500
G^1J^1	−23,400	+9,800
J^1J	+5,000	−9,200
J^1K^1	+11,400	+45,500
K^1L^1	+5,000	+6,000
L^1M^1	−74,000	−13,000
J^1N	−65,600	−2,700
M^1N	+18,600	+54,800

N. B.: + is compression; − is tension.

From Fig. 2 the maximum bending on column occurs at foot of knee brace and equals 11,850 lbs. × 12 = 142,200 ft. lbs., requiring a flange area of 9.48 sq. ins. to provide for bending, assuming the column 18 ins. back to back of angles and a fiber stress of 10,000 lbs. per sq. in., while Mr. Hutchinson would require 16 sq. ins. extra flange area for the same dimension column on his assumption of a fixed end column.

It is hardly necessary to state that Mr. Hutchinson's methods are not used in the general design of Mill Buildings.

Yours truly,

W. H. Dunham,
Lackawanna Steel Co.

Buffalo, N. Y., July 5, 1904.

Concerning the Nature of Shearing Stress.

Sir: I have been impressed with the almost universal classification of stress by the authors of text-books and in technical literature generally, under three headings: Tension, Compression and Shear; whereas it appears to me that final analysis shows only two elementary divisions, namely, Tension and Compression. Other divisions, including Shear and Torsion, which appear at first sight to be elementary, are merely involved combinations of tension and compression.

While no practical error results from this method of consideration, it would appear to be more scientific and to facilitate the analysis of stress in general to have this fundamental conception of the subject clearly defined.

With a view to explaining the grounds on which I base the claim that shear should not be classed as an elementary form of stress along with tension and compression, I beg to submit below an analysis of shear into its component parts.

Assume first a square frame as shown in Fig. 1, of homogeneous, elastic material; the members having a section of unit area, and the sides being of unit length, with joints closely fitting and without friction. Now consider parallel forces, each of amount p, applied to this frame at the corners as indicated in Fig. 2. Stresses will develop in the members of the frame of amounts indicated by the letters p_1, p_2, p_3; tension being indicated by the sign +, and compression by the sign −. Assuming now that the forces p are not sufficiently large to distort the frame appreciably from the shape shown; noting also that the sides of the unstressed frame are of unit length, and that the cross-section of each member is of unit area; assuming the material to be of steel the coefficient of elasticity of which in tension and compression is 29,000,000 lbs. per sq. in.; and letting s_1, s_2, s_3 denote the strains or extensions of the various members corresponding with the stresses p_1, p_2, p_3, respectively; then there may be written the following equations:

$$p_3 = \frac{p_3}{\sqrt{2}} \tag{1}$$

$$p = p_1 + \frac{p_3}{\sqrt{2}} = p_1 + p_2 \tag{2}$$

$$\frac{p_1}{p_2} = \frac{s_1}{s_2} \tag{3}$$

$$\frac{p_3}{p_3} = \frac{s_2}{s_3}\sqrt{2} \tag{4}$$

hence

$$s_3 = 2\,s_2 \tag{5}$$

But also,

$$(1 + s_1)^2 + (1 - s_2)^2 = (\sqrt{2} + s_3)^2 = 2\,(1 + s_2\sqrt{2})^2 \tag{6}$$

$$s_1 = \frac{p_1}{29{,}000{,}000} \tag{7}$$

$$s_2 = \frac{p_2}{29{,}000{,}000} \tag{8}$$

Based on above assumptions and equations, the amount of stress p_1 is about 4-5, and p_2 about 1-5 of the applied force p.

Next consider the frame of Fig. 1 to be acted upon by forces as indicated in Fig. 3; stresses will again develop in the members of the frame of amounts indicated by the letters p'_1, p'_2, p'_3, as in the case of Fig. 2. Making the same assumptions as for Fig. 2, similar equations may be written to show that stress p'_1, is about 1-5, and p'_2 about 4-5 the applied force p. Stress p'_3 in diagonals will be of same amount as p_2 but of opposite sign.

Now, considering, as shown in Fig. 4, a combination of the loadings in Figs. 2 and 3, stresses p_3 and p'_3 balance each other and consequently the stress in diagonal members is zero; the complementary stresses p_1, p'_1, and p_2, p'_2 acting together produce stresses in the side members equal in amount to the applied force p.

Applying this practically, we have in Fig. 2 an illustration of what happens, approximately, when tension is

developed in a test piece or tension member of a structure; A, B, C and D, representing molecules of the material, and members of the frame representing the cohesion that is known to exist between them. It will be noted that the force p, which is that measured by the testing machine, is resisted by the stress p_1, together with the component of p_2 parallel with p_1. In other words,

$$p = p_1 + (p_2 \div \sqrt{2}) \quad (9)$$

Whereas by the ordinary method of consideration the force p is assumed to be resisted entirely by the stress p_1, or as indicated by the equation,

$$p = p_1 \quad (10)$$

Comparing (9) and (10), it is evident that the tension or cohesion between the molecules of the material as determined ordinarily includes also the effect of this diagonal resistance and is therefore not a true measure of the cohesion between the molecules.

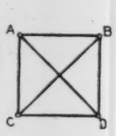

Fig. 1.

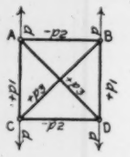

Fig. 2.

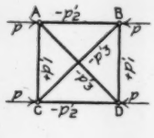

Fig. 3.

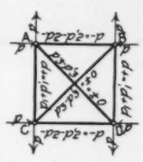

Fig. 4.

A more accurate method of determining the tension or cohesion between the molecules of a material would consist in the application of conditions indicated in Fig. 4, namely, applying transverse compression of amount equal in intensity to the direct pull. The direct pull would then represent closely the cohesive or tensile resistance between the particles, the diagonal resistance represented by p_3 being eliminated. This method of testing would, however, be difficult of application practically, and besides, the ordinary method conforms more closely to the actual conditions under which the material is used in practice.

It must be borne in mind that the similarity between the stressed frame work of Fig. 2 and what takes place between the molecules of material admits of no exact quantitative comparison; the diagonals of the frame are clearly defined members free to extend or compress under stress, whereas in the latter case the diagonals are represented by the combined attraction between the molecules under consideration and all others not in direct line with the applied force. Moreover, as the fibers of material change in length under stress, they tend to change in position and thus interfere with each other, producing secondary stresses which complicate the problem materially.

Applying the above reasoning to shear, there is shown in Fig. 5 the make-up of an ideal girder, consisting of tension and compression chords with a web made up of many small tension and compression members at right angles to each other and at an angle of 45° with the vertical, connected at their ends to each other and to the chords as by a rivet. The load W is assumed to be transferred to the web system by rivets at intersection of the web members as indicated. As thus analyzed we have in reality a multiple intersection truss and the stresses are determinable as for such.

In this diagram the width of lines is made to vary approximately in proportion to the stress in the member.

In Fig. 6 is shown the web system separated from the rest of the structure, and at "a" and "b," portions of web system are removed, forces being substituted for the corresponding stresses in parts removed. The forces (shown by arrows), at "a" are all equal to each other, and likewise those at "b" are equal to each other though of smaller amount than those at "a" for this particular location of the load W.

It will be seen that the same condition exists at "a" or "b" as that illustrated in Fig. 4.

Assuming now that the members of the web system are very numerous and close together, and that there is no deflection to distort the rectangular shapes shown at "a" and "b," (in other words, assuming that provision has been made in construction that the lengths of all members, under such stress as would be induced therein by this loading, shall be as indicated), and letting,

A = area of web members as cut by plane X-X;

S = the unit shear as ordinarily understood;

p = stress in web members as indicated by the arrows at "a" per unit of area; and

R = End Reaction of Girder as indicated on Fig. 5,

Then follows, when the web members are close together,

$$S = \frac{R}{A}, \text{ and} \quad (11)$$

$$p = \frac{\frac{R}{2}\sqrt{2}}{\frac{A}{\sqrt{2}}} = \frac{R}{A} \quad (12)$$

Comparing (11) and (12), it will be seen that S and p are equal; in other words the shear as ordinarily understood, is closer to the real cohesive or tensile strength of the material than the tensile strength as ordinarily determined by the testing machine.

The value of "shear" for steel is generally taken at about ⅔ to ¾ its tensile strength, which corresponds approximately with the ratio between p_1 and p in Fig. 2 above.

Thus, the "Shearing Stress" as ordinarily understood and as used in connection with webs of plate girders, etc., is correctly applied, but instead of being a division of stress in itself, is in reality the sum of the vertical components of a tensile and a compressive stress.

In comparing the ideal girder above with the girder of actual practice, it must be borne in mind that only the principal stresses have been considered, and assumptions made to eliminate all others, whereas in actual girders no such assumptions are allowable. Varying deflection under varying load involves distortion of shape from that shown; in other words, the fibers change in position, thus interfering with each other and thereby producing secondary stresses the effects of which have not been considered, and which in turn react upon the principal stresses to an extent determinable only by experiment.

"Shear" as applied to the stresses produced as in dividing a plate by shears or in punching a rivet hole, is different from shear as applied to the stresses in a girder discussed above, and in this sense the term is not correctly used.

The dividing of a plate under the action of shears is effected by a combination of local failures starting usually by crushing of the material immediately under the knife edges and so continuing to fail at the weakest points until the parts are completely severed; the operation is not accompanied by clearly defined stress distributed uniformly over the cross-section as in the case of the girder.

It is evident that in cutting cheese with shears the so-called "shear" in the cheese is practically absent except immediately under the blade, whereas in cutting similarly a piece of steel, there would be considerable shear all through the section, though variable in amount, being maximum at the points of application of the blades, and decreasing towards the center from each side. This difference between the cutting of cheese and of steel is due to the greater hardness of the steel than of the cheese, though both are fairly good illustrations of practically homogeneous elastic material such as the theory assumes.

As further illustrating the difference between this shear and that which exists in the web of a girder, the appearance of fracture produced by shearing a plate or punching a rivet hole, shows how the stress has been more concentrated at the outside of the material than towards the center, and the failure by localized crushing under the knife edge is generally quite perceptible.

Respectfully, Chas. Worthington,
M. Am. Soc. C. E.

Pittsburg, Pa., August 9, 1904.

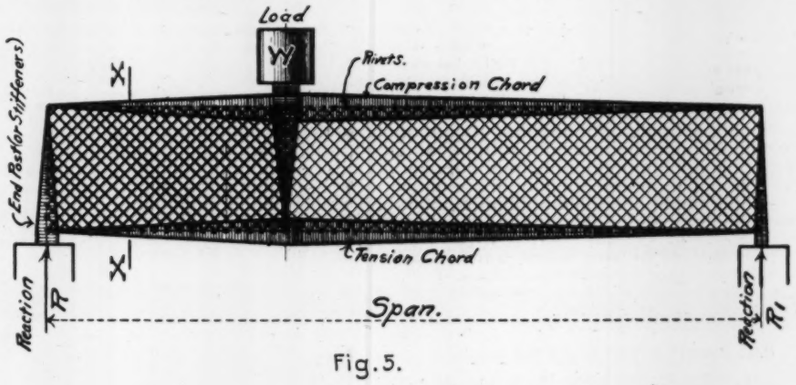

Fig. 5.

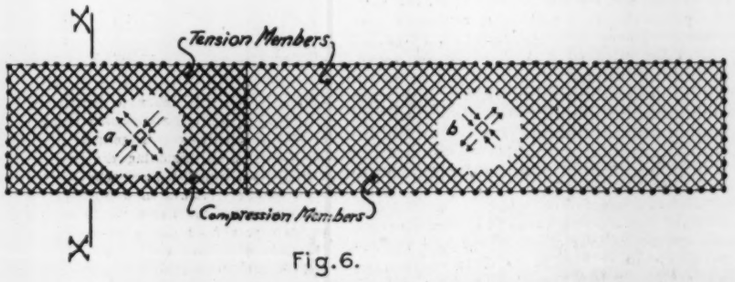

Fig. 6.

Notes and Queries.

E. C. writes:

While illustrating the different wrinkles to adjust the plumb-bob string please show our old friend and everhandy companion—any *button* large enough to allow the string to be threaded through two of its holes. It's just as good" as Mr. Colburn's rubber comb, and easier to get.

A PECULIAR ACCIDENT caused a shut-down of the electric power house of the California Gas & Electric Corporation recently. Workmen were excavating for a new pipe line down the face of the bluff to supply additional generators. A blast was set off, contrary to orders, and dislodged a rock which rolled down the hill, struck one of the cast-iron pipes which was under pressure and caused a piece to break out. The stream of water escaping from the break under heavy pressure washed away the earth on the hillside and sent an avalanche of mud and water down into the power house, which continued until the headgates above could be reached and the water shut off from the broken pipe. The advantages in case of such an accident of having the gates at the head of the pipe line operated by electric motors controlled directly from the power house, as in the plant at Electron, Wash., described in our issue of Sept. 29, will be obvious.

A PACIFIC OCEAN OUTLET FOR THE CHAGRES River is reported as having been found by the American engineers, under Chief Engineer J. F. Wallace. The disposal of the flood waters of the Chagres River has been one of the very serious problems confronting the engineers of the Panama Canal; and under the high level plan for the canal the estimated cost of this Chagres control was $36,000,000. Mr. Boyd Ehle, one of the canal engineers, was sent out with a party some months ago to explore the head waters of the Chagres River. Owing to the dense tropical jungle this work was very difficult, but they found rivers where none were indicated on the maps made by the French engineers, and could not find rivers there shown. About 12 miles from the canal line they found a river leading down the Pacific slope into which the waters of the Chagres could be diverted by works estimated to cost $16,000,000. This would make a saving of $20,000,000 in the cost of the canal and at the same time solve one of the greatest engineering difficulties in its construction.

BIDS FOR SALT WATER FIRE MAINS for the Borough of Brooklyn are to be opened on Oct. 12 by Mr. John T. Oakley, Commissioner of Water Supply, Gas and Electricity of New York City. The mains are designed to give high pressure fire protection for the water front and dry goods district of Brooklyn. The contracts are to be let in three sections, and the total estimated cost of the work is $650,000. Bids for pumping stations will be invited later on.